NIST
Center for Nanoscale Science and Technology
Nanofab Safety Manual

NIST CNST Nanofab
Building 215, Room D101
100 Bureau Drive
Gaithersburg, MD 20899

This manual was prepared for users and staff of the NIST CNST Nanofab. Any comments or questions regarding the content of this manual should be directed to:
Russell E. Hajdaj, Nanofab Assistant Manager/Safety Coordinator at rhajdaj@nist.gov

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NIST CNST Nanofab Safety Policy

The Staff and Management of the NIST Nanofab have implemented all reasonable measures to ensure that the laboratory provides a clean and safe working environment.

It is the responsibility of all users and staff to act in a professional, courteous, and safe manner at all times while in the facility. Users violating the operating and safety rules of the facility or endangering the safety of themselves or others users, will be denied further access to the laboratory at the sole discretion of the management.

The NIST Nanofab Management

1. Introduction

This safety manual was developed by the NIST CNST Nanofab Assistant Manager/Safety Coordinator, and is specifically designed for the NIST CNST Nanofab Cleanroom. This manual is in compliance with all Federal Regulations and in accordance to OSHA Laboratory Standard, 29CFR 1910.1450, and NFPA 318, Protection of Semiconductor Fabrication Facilities. This document is a reference manual covering the basic operational policies for use of the NIST CNST Nanofab at NIST. It applies equally to all users and staff, and governs both safety and laboratory rules. All users are expected to have read and understood these procedures. This booklet, along with the mandatory safety training and written safety examination, is also expected to be sufficient training and notification for the Right-to-Know regulations for Laboratory Workers. Laboratory workers are expected to have a technical level sufficient to understand everything in this booklet.

The Nanofab laboratory is located in the Advanced Measurement Laboratory (AML) Complex in Building 215/Room D101. This Laboratory is a NIST-wide multi-user facility with over 80 certified users. The facility houses a multi-million dollar investment of semiconductor equipment that is fragile, and sensitive as to how it is used; the facility also houses toxic gases and chemicals, which pose significant hazards if handled incorrectly. This booklet attempts to document acceptable operating behavior for use of the Nanofab. It is impossible, however, to define a policy for every conceivable situation. Rules and policies are no substitute for **common sense**. Under these conditions, anyone who fails to act in a professional, safe and responsible manner while in the Nanofab will be banned from further use of the facility at the discretion of the management.

Users' suggestions and feedback on the facility, its staff, its operation, and its equipment are welcome at all times. Please feel free to direct your suggestions to whomever you feel the most comfortable with.

2. General Lab Procedures

2.1 Access

Access to the Nanofab is only granted to certified users and facility staff who have completed the required Start-up and Safety Orientation, and have completed the **yearly** Safety Certification Examination with a passing grade. The user will be granted access that will allow personal access at any time during operating hours (see section 2.6). Use of the Facility is a privilege that can be revoked by the facility management at any time.

2.2 New User Orientation

A Start-up and Safety Orientation Program has been developed by the Nanofab Safety Coordinator and must be attended by the prospective user, and is required before access to the facility is granted. The orientation is typically conducted in groups, but can also be conducted on a scheduled individual basis. The orientation is a two-part session. The first part includes a general presentation discussing how to use the facility and a Hazardous Products and Facility Safety presentation, followed by a facility tour. The second part is a written safety examination. Part 1 takes approximately 3 hours. The exam can be taken anytime, but must be completed with a passing grade before an access badge can be obtained. Completing the examination is evidence that the user understood at least 95% of the information presented. This safety exam must be taken every year. If the exam is not completed with a passing grade or you do not take the exam, your existing access privileges will be deactivated until the exam is completed with a passing grade.

2.3 Locations (See Facility Layout, section 9.0)

- **Main Entrance (Bldg 215/rm.D101):** This area can be accessed by users, staff, NIST Environmental Services, and authorized NIST Plant Personnel during normal operating conditions. The door is locked during outages, emergency procedures and under abnormal conditions. **Do not bring fresh chemicals, waste chemicals, or cleaning products through the main entrance.**
- **Lockers Rooms:** The lockers and hangers are for regular users (at least one day per week). Non-frequent users, Visitors, and Students can occupy an empty locker on a daily basis, but will not receive an assigned locker unless it has been determined by the Facility Manager that a locker assignment is necessary. The locker is for your personal belongings, street clothes and shoes, coats, cell phones, valuables, wafer boxes, notes, etc. **Do not keep chemicals in lockers or in the gowning area**.
- **Gowning:** This area is a controlled environment and should only be accessed by certified users. Approved visitors can access this area when accompanied by a certified user, or a facility staff member. Do not bring dirty or questionable items into this area. **Do not bring process chemicals through the gowning area. This includes fresh chemicals, chemical waste, and cleaning products. Use the approved chemical pass-through for transferring chemicals into the cleanroom.**
- **Cleanroom:** The cleanroom areas can be accessed by a certified user, facility staff, Environmental Services, authorized Plant Personnel, and authorized visitors if accompanied by a certified user or facility staff member. Frequent entry and exit is discouraged. The work conducted in the cleanroom is performed with toxic gases, hazardous chemicals, and potentially dangerous equipment. Always be aware of those who are working around you. Move carefully throughout the cleanroom so you do not disturb, or interfere with work being conducted. Chemicals are periodically refreshed and are introduced into the cleanroom by the user or facility staff. The chemicals for the cleanroom are retrieved from the chemical storage areas (room D106) and properly transferred (see section 5.1

Chemical Handling) to the service chase(s) adjacent to the cleanroom bay and placed into the appropriate chemical pass-through (acid or solvent).

- **Service areas:** These areas are identified by signs displaying **"Restricted area Nanofab Staff Only"**. Users are discouraged from entering these areas unless required to do so. Staff and users are discouraged from entering the service areas from the cleanroom unless absolutely necessary. Proper entry to the service areas is from the Class 1000 hallway (use pre-gowning protocols). The service areas are hard to see from the cleanroom and if a person is injured, it may be difficult for them to receive help. Facility Staff members can access this area when needed. The areas under the raised floor can be accessed by facility staff, and NIST Physical plant only. The service areas in the sub-fab can only be accessed by facility staff, and NIST plant personnel. The Liquid Nitrogen Area outside bldg. 215 can be accessed by facility staff, Vendor Delivery Personnel, and Plant personal only.

2.4 Cleanroom Behavior

This Government Research Laboratory is a Class 100 Cleanroom, where proper behavior and a professional attitude are required at all times. This facility is used NIST wide and many sensitive experiments with many hours of work are taking place on a regular basis. You must act in a manner that will not disrupt, or disturb other researchers using the facility. As a user of the facility you are responsible for reporting any activities that deviate from normal behavior. The violator(s) may lose facility privileges based on the discretion of the Nanofab Management.

2.5 Hours of Operation

The normal hours of operation are 7:00 am to 7:00 pm. Usage outside of the operating hours must be authorized by the facility manager. Authorized users utilizing the facility outside of the operating hours must have authorization and comply with any and all responsibilities dictated by the Nanofab Management.

2.6 Security Cameras

Security cameras are located throughout the facility, and in other areas of the cleanroom. This allows 24 hour remote monitoring of the Cleanroom. The Camera system has a digital storage capability for 2 months of video recording. The Nanofab staff and the NIST Emergency Services Division will have the capability to monitor the activities within the facility from a remote location at any time.

2.7 User Communication

All users must supply the facility manager with a working email address that they can check on a daily basis for messages relating to the facility. Email is the primary communication device to notify the users of outages, High-level tours, equipment status, etc. Questions, comments, or suggestions about any safety issue, this manual, or other concern can be directed to any member of the Nanofab, at any time.

2.8 Facility Governance and Appeals

The Nanofab Management of the facility is responsible for the continued operation and existence of the facility. Use of the facility by any user is at the sole discretion of the management. The Facility manager and facility staff are responsible for maintaining and enhancing the equipment resource of the facility, and for assuring that the operational policies of the facility are followed. On matters involving equipment usage or safety, you must follow the direct instructions of the facility staff. Both staff and user are expected to act in a courteous and professional manner at all times. Deviations from this norm by either users or staff should be reported to the Facility Management immediately.

If at ant time you, as a user, feel that you have been unfairly treated by a staff member or strongly disagree with the rules imposed by a staff member, please discuss the situation with the Facility Manager.

2.9 Nanofab Safety Committee

The Nanofab Safety Committee is organized to promote increased safety in Nanofab operations. They review safety policies, procedures, and recommend changes to implement best practice operations. The group consists of NIST employees with various backgrounds. Their names and contact information can be found below.

Name	Title	Department	email	Office Phone
Russ Hajdaj	Nanofab Asst. Manager/Safety Coordinator	Center for Nanoscale Science and Technology (CNST)	rhajdaj@nist.gov	301-975-2699
James "Mike" Blackmon	NIST Safety	NIST Safety	Mike.blackmon@nist.gov	301-975-5822
Dennis Myers	NIST Safety	NIST Safety	dennis.myers@nist.gov	301-975-5823

Nanofab Safety Committee

3. Equipment use

3.1 Approved Users

Access to the facility itself does not permit use of any particular instrument. The equipment in the facility is hands-on equipment for the certified users. The equipment in the facility is highly sophisticated and delicate, and can be potentially hazardous if not used properly. Each instrument has operating instructions, restrictions, and safety rules in place to ensure the continued operation of the instrument and this is strictly enforced by the Facility Staff and Management. Failure to follow the operating procedures or rules can result in injury, expensive equipment damage, and unaffordable downtime. Consequently, careless or damaging use of the equipment will result in suspension of users' privileges, either for a specific instrument or the facility as a whole.

3.2 Equipment Operations

Operating procedures are presented to the user during equipment training and should be maintained by the user for future reference. Operating procedures and instructions manuals are available online at the following website.

http://nanofab.cnst.nist.gov

3.3 Equipment Problems

For the safety of the user, please report all equipment damage or malfunctions to the Facility Technician(s). **DO NOT TRY TO REPAIR THE PROBLEM YOURSELF**, this could result in injury, expensive damage, and extended downtime.

4. Laboratory Practices

4.1 Visitors

Visitors into the facility must be authorized by the facility management and escorted by a staff member or certified user. Visitors are not allowed, for any reason, to operate equipment, use chemicals, or to be left alone. An authorized service contractor may be left alone, but must first be authorized by the facility manager and must be provided access to a contact person at all times.

4.2 User Storage

Do not store chemicals in user storage lockers. All chemicals are to be stored in an approved area and the container must be labeled properly.

4.3 Phones

There are phones throughout the facility. Inside the cleanroom there are 12 phones located near the main center hallway at the ends of the work bays. The cleanroom phones are large, easy to see, hands free operation. The phones can be used for person-to-person communication, paging, and for emergencies. There are wall mounted phones located around the perimeter of the cleanroom in the visitor corridor. For emergencies at NIST call x2222.

Emergency calls: When an injury occurs in the facility, the caller must provide the room number (located above cleanroom phones) and the type of injury to the emergency responder.

4.4 After Hours Usage

The current hours of operation are from 7:00 am to 7:00 pm. After hours usage must be authorized by the facility management. The buddy system must be employed if applicable. A visitor does not qualify as a buddy. The buddy system requires a certified user or facility staff member to be available at all times.

The Nanofab Management has also implemented a live camera system that covers every lab bay and chase. This can be monitored by Nanofab Staff and the NIST Emergency Services Group (Fire Dept.) in real-time. If the buddy system above is not possible, the user will be allowed to work after hours if the following procedures are followed.

1. Obtain authorization from the Nanofab Management.
2. The Management will notify the Emergency Services Group.
3. The user will contact the Emergency Group both before entry and when departing from the facility at extension 2805 (non-emergency #).

4.5 Facility Shutdown

Facility shut downs are regularly scheduled events and also occur in the event of a storm, building faults, emergency, etc. A facility staff member is responsible for containing the process gases, and properly shutting down the power to predetermined areas of the facility to eliminate the chance of fire or equipment damage. During the time of the shut down, the facility will be locked and no access will be granted for any reason.

4.6 Safety Glasses/Contact Lenses

Safety Glasses are required at all time when working in the facility. There are safety glasses available to all users in the gowning room. You can keep them in your locker, but they must be returned when you no longer intend to use the lab. Visitors are required to wear safety glasses. Contact lens use in laboratories has been

disputed for years. The American Chemical Society has approved the use of Contact lenses for laboratory workers, and they are permitted in the Nanofab, but are not a substitute for safety glasses. A second pair of contact lenses or prescription glasses is recommended as a backup.

4.7 Facility Alarms/Facility Evacuation

There are numerous alarms in the facility. The user must be able to identify the alarm quickly, and act accordingly. If you cannot identify the alarm leave the lab immediately through the nearest exit and notify facility staff.

Types of Alarms:

- **End of Cycle Alarm:** Some alarms signify end of cycle on some instruments; these are usually not very loud, and may be recognized by a repetitious beep.
- **Exhaust Failure Alarm:** Only activated in the main control room. The individual Nanofab tools themselves will alarm when the tool senses loss of exhaust. Contact a Nanofab Staff Member.
- **Fire Alarms:** These are located throughout the facility. They can be recognized by a flashing strobe and horn. Some of these devices provide verbal instructions, but you are required to leave the lab immediately and *do not stop to remove your gown*. Assemble outside in the small parking lot on South Street in front of the building, so you can be accounted for. *You are also required to leave the lab in the event that the fire alarm was sounded for a practice drill.*
- **Toxic Gas Detector Alarms:** These are identified by a loud repeating beep with the activation of the yellow flashing evacuation strobe. You are required to leave the lab immediately.
- **Power Disruption/Power Loss, HVAC Failure, Chemical Exhaust Failure:** Only activated in the main control room. The individual Nanofab tools themselves will alarm when the tool senses loss of exhaust. Contact a Nanofab Staff Member.

Emergency Evacuation Procedure:

1) Do not stop to remove your gown.
2) Contain any hazardous work in progress if possible.
3) Leave the lab through the nearest exit.
4) Avoid heading towards the Oxidation/Diffusion Furnace room (B106).
This area has many of the hazardous gases being used.
5) Assemble outside in the small parking lot on South Street in front of the building, so you can be accounted for.

4.8 Injured Person Retrieval

A person injured in the lab may require immediate attention. Safety is the number one priority of this facility. It may be required that safety personnel enter the facility without following the cleanroom protocols. They are trained to retrieve or treat the person on the spot if it is required to do so.

5. Chemical Safety

5.1 Handling/Labeling

Handling chemicals in the facility is a common practice. Chemicals are retrieved from the chemical storage area (room D106) and are introduced into the cleanroom via an airlock or pass-through.

- **Transport:** Use bottle carriers when transporting bottles, *especially* glass bottles. Use the chemical cart if transporting multiple bottles. Do not transport chemicals that are incompatible with one another. Never transport acids with solvents or bases. Acids produce heat from an exothermic reaction and can ignite solvents. Acids that mix with strong bases produce violent reactions that can cause the chemicals to suddenly splash onto the user.
- **Chemical Deliveries:** Chemicals are delivered to the bldg 215 loading dock, and will require transport to the dumb-waiter room (D08) located immediately outside the sub-fab area. This area can only be accessed by the Nanofab Facility Staff. **Do not place acids in dumb waiter with solvents or bases.** The Nanofab Staff Member will retrieve the chemicals from the dumb-waiter located upstairs in room D107, wipe them down, and place them into the appropriate chemical closets. All bottled chemicals must be handled with chemicals resistant gloves and eye protection. It is a recommended practice to wash hands after handling chemicals and chemical containers.
- **Pouring:** move slowly, and hold the bottle with two hands. One hand should be firmly around the neck and the other hand should support the bottom of the bottle.
- **Labeling:** Federal regulations require all containers must to be properly labeled with contents and contact. You can use the plastic ID labels when using chemicals in Petri dishes or beakers. For short term use, you may also write the chemical and contact information on a cleanroom wipe and locate it under the container. The NIST labeling guide has been provided for your reference. (See appendix for NIST labeling instructions, section 10).

5.2 Personal Protective Equipment

Personal Protective Equipment (PPE) is mandatory when using chemicals. Special protective equipment is required for HF processing and toxic gas bottle changes. Some chemicals and toxic gases require specialized PPE training, and this equipment cannot be used without proper training. The protective equipment used in the Nanofab is listed below (Approved by Nanofab Asst. Manager/Safety Coordinator):

- Acid Aprons
- Latex gloves*
- Protective chemical sleeves
- High-wrist neoprene or nitrile gloves
- Face shield and safety glasses
- Self Contained Breathing Apparatus (SCBA-training and certification required every two years)
- Corrosive Protection Suit (Emergency Responders)

* Latex gloves used in the facility provide minimal chemical protection, and are primarily used to control human particulate contamination.

PPE Certification and testing:

- Chemical Gloves: You can check the chemical protective gloves for holes by filling the glove with nitrogen and immersing it into a water bath to see if any leaks are present. If a glove has holes or looks damaged, discard the glove and replace with new gloves. See Appendix for chemical protective glove resistance guide.
- SCBA Equipment: This equipment must be cleaned and tested every six months. This is coordinated by the Nanofab Safety Coordinator with NIST Fire Protection Group. This is conducted every six months to ensure the operability of the equipment.

PPE Training:

For PPE to be effective, proper use is essential. Below describes the procedures required to provide the maximum protection when using the supplied PPE.

- Chemical Resistant Apparel
  - **Adjustable face shield:** This is used with safety glasses. It can be adjusted to fit most head sizes. There are adjustment knobs on the straps that can be used to tighten the apparatus around the head. There are other adjustment knobs that can be used to make the face shield snug and secure. Do not use face shield if the adjustments are too loose, it may fall off the head or obscure the users vision.
  - **Chemical Gloves:** Choose gloves that fit over the protective latex glove, which are not too loose or too tight. A glove that is too loose will not provide the required dexterity needed to use the chemical process equipment (i.e. Timer buttons, tweezers, wet bench controls, etc).
- Toxic Gas Safety Equipment
  - **SCBA:** This equipment can only be used by trained individuals who have completed the required medical exam, and have completed fit testing and training. The certification for SCBA equipment is good for two years. The user of this equipment is required to view a video on Compressed Gas Safety (once per year) before the equipment can be used. The medical exam and the fit-testing can be arranged by the Facility Assistant Manager/Safety Coordinator, and is conducted on the NIST Gaithersburg Campus.

5.3 Spills

Chemical spills are an area for concern because there can be multiple exposures from the spilled material, equipment damage, and potential facility destruction. NIST has a trained HAZMAT Team that will clean up the spill, and they can be contacted at x2222. Describe what chemical was spilled, and provide them with the MSDS (see section 5.5) information. In the event that a small spill (less than 200ml) occurs, or Acetone is spilled, this can be contained using the spill supplies (rags, spill socks, and pillows), report the spill and contact the facility technicians immediately. The spill supplies are located in the service chases that serve the chemical work bays.

Spill Procedures:

- **Exposure:** If you are exposed to the spilled material, do not stop to contain the spill. Remove contaminated clothing, and rinse with copious amounts of water, and seek assistance. Your health and life is the first priority in a situation that involves a chemical exposure from a spill; the spill will be cleaned up after you are cared for.
- **Containment:** Acetone or small volume (<200ml) only. Place spill socks and pillows around the spill so it does not migrate under or near a source

of ignition. **DO not call for assistance from the area where the spill is located,** this can trigger an explosion.

- **Evacuate:** inform the users in the lab that there has been a chemical spill and that they need to leave the lab until the spill is cleaned up.
- **Response:** Call x2222, and report the spill. Contact facility manager. Fill out an accident report.

5.4 Eyewash Stations and Showers

The proper use of an eye wash station requires the user to activate the eyewash, and using the thumb and fingers, hold open the eyes, and rinse for several minutes. The user or buddy must call NIST Emergency Services at x2222. There are eyewash stations and showers available in the facility and the locations are listed below.

- **Eyewash stations**
  - At the ends of the chemical wet benches
  - In the class 1000 corridors immediately outside the cleanroom proper.

- **Safety Showers**
  - In the class 1000 corridors immediately outside the cleanroom proper.

5.5 MSDS

Material Safety Data information is provided in hard copy format, and is located in the main entrance in room D101. You can also find Up-to-date MSDS information on the internet by searching the following keywords: *MSDS, Material Safety Date Sheets, chemical name or on the chemical manufacturer website*. This data provides information about a particular chemical such as its hazards, storage procedures, first aid, long-term exposure, etc. There are many online sites that provide this information for free. Chemical vendors are required to provide MSDS information when purchasing chemicals. The NIST emergency response team has this information available from a CD and they have access to MSDS information from online.

5.6 Approval

New chemicals that enter the facility must be authorized by the Nanofab Management and must be accompanied by their MSDS information. This is to ensure compatibility with all current chemicals and processes.

5.7 HF Safety

Hydrofluoric acid (HF) is commonly used in the facility in various concentrations. You may be exposed to HF even if you do not use it. The areas where HF is used and stored are well identified by HF Acid danger signs. Stay alert and work carefully in these areas of the facility. If you are exposed to HF follow the procedures listed below.

1) Remove contaminated clothing.
2) Rinse with copious amounts of water.
3) Apply Calcium Gluconate gel, massage into affected area.
4) Call x2222 to report the incident.
5) Fill out an accident report.

5.8 Chemical Storage

Chemicals are to be stored in the properly designated areas, see facility layout for chemical storage areas. Use chemicals in an approved fume hood. The Nanofab has separate chemical fume hoods for solvents (bases) and acids, and the hoods are labeled accordingly. Do not store incompatible substances next to each other. If you do not know what chemicals are incompatible, contact a facility staff member or the facility manager before using chemical. Never store a solvent next to an acid, because acid produces heat from an exothermic reaction. Never store chemicals in your locker.

5.9 Pregnancy

Users who may be pregnant are not restricted from using the facility, but may want to discuss the situation with a NIST safety representative, their group leader, or the facility manager. Some chemicals such as solvents and photoresist can be harmful to the unborn fetus.

5.10 Waste and Disposal

Chemical waste generated in the facility must be stored in a properly labeled container (see appendix for proper labeling) and placed in the designated storage areas under the fume hoods. When the waste storage is full, contact the Nanofab Technicians (see contacts on page 14) so the waste can be properly disposed of. The chemical waste bottle(s) will be placed in a compatible chemical cabinet in the chemical storage room D106. The Nanofab staff will contact NIST Safety and the waste chemicals will be retrieved for disposal from room D107.

5.11 Chemical List (See Appendix)

6. Gas Safety (See appendix for NIST Compressed Gas Safety Information)

6.1 Compressed Gas Delivery Emergency Response Program is in place in case of a catastrophic release of HPM (Hazardous Process Materials) upon delivery. This is the responsibility of the NIST Fire Protection Group. If there is a compressed gas delivery accidental gas release, leave the local area and contact x 2222 (HAZMAT), and report the incident and the location.

6.2 Hazardous Gases Used

The following compressed gases are used in the Nanofab.

Gas	Assay	Hazard	Usage point	Location	Gas Cabinet ID
100% Silane	SiH4	Unpredictable, burns in moist air. Toxic.	LPCVD	B106	HH-1
5% Silane/Helium	SiH4+He	Unpredictable, burns in moist air. Toxic.	PECVD	B106	HH-9
Dichlorosilane	SiCl2H2	Corrosive, Toxic	LPCVD	B106	HH-3
Ammonia	NH3	Corrosive, Toxic	LPCVD,PECVD	B106	HH-5
Hydrogen	H2	Flammable	ATM Furnaces	B106	HH-8
Oxygen	O2	Supports combustion	ATM Furnaces, RIE, PECVD, LPCVD	B106, B105	NA
Sulfur Hexafluoride	SF6	Low toxicity level	RIE, PECVD, DRIE	B105, B106	HH-4
Trifluoromethane	CHF3		RIE	B105	HH-7
Nitrous Oxide	N2O	Asphyxiation	RIE, PECVD, DRIE	B105, B106	HH-2
Nitrogen	N2	Asphyxiation	Facility Wide	Facility Wide	NA
Forming Gas	N2/H2	Flammable	ATM Furnaces, RTP	B106,	HH-8
Octafluorocyclobutane	C4F8	Asphyxiation	Deep Silicon Etcher	B105	HH-7
Boron Trichloride	BCl3	Highly Toxic	Metal RIE	B105	HH-6
Chlorine	Cl2	Corrosive, Highly Toxic	Metal RIE, Metal ICP	B105	HH-6
Carbon Tetrafluoride	CF4	Asphyxiation	RIE	B105	HH-2
Argon	Ar	Asphyxiation	Sputter, ATM Furnaces, RTP	B104, B105, B106	NA

6.3 Cylinder Leak Check

Process gas cylinders should be checked for leaks before receiving delivery. This is typically done by the delivery outfit before loading the truck and on-site before receiving the gas delivery.

6.4 Toxic Gas Cylinder Change out

Toxic (and pyrophoric) gas cylinder change-out is a two-man operation. Both individuals are required to wear SCBA equipment during cylinder change-out. The hallways leading to the sub-fab area must be barricaded until the cylinder is installed. A call to the NIST Fire Protection Group must be placed, providing the information that a toxic gas cylinder change-out is in progress. A return call must be placed after the installation is completed.

6.5 SCBA Program

The requirements for using a Self Contained Breathing Apparatus at NIST are a medical exam, fit test, and usage training. This is coordinated by the Nanofab Assistant Manager in conjunction with the NIST Medical Unit, NIST Fire Protection Group and with the NIST Safety Office. The certification is good for two years.

6.6 Highly Toxic Gases Used

Currently, the Nanofab has only two gases that are considered highly toxic, Boron Trichloride and Chlorine. These gases are used in the metal etching systems in room B105. If Chlorine odors are detected, evacuate the facility and contact a Nanofab staff member. If a staff member is not immediately available, call the HAZMAT Team at x2222, and report the odor.

Remember, when in doubt, GET OUT!

6.7 Toxic Gas Handling and Usage

Proper handling and training is required when using toxic gases. **All** gas cylinders are to be transported using and approved cylinder truck with attachable chain. Gas bottle hook-up must be done with two people and a Scott Pack SCBA if toxic gases are used. All gases are to be handled by the facility staff only. Users are not authorized to access the gas cabinets located in the sub-fab locations.

When opening a cylinder of process gas, just open the valve enough to get the gas pressure up, but **do not crank the valve all the way open**. When the valve is cranked wide open, it can be mistaken for a closed valve. Place appropriate signs for charged process gas lines inside the cabinets so that it is visible from the closed door position.

7. Emergency Services

7.1 Fire Response

At NIST the emergency number for a fire in the lab or building is x2222.

7.2 Chemical Spills

Chemical spills at NIST can be reported to the Fire department at x2222. Be prepared to provide all pertinent information to the Fire Department such as **what**, **where** and **how much** was spilled.

7.3 Medical Emergencies

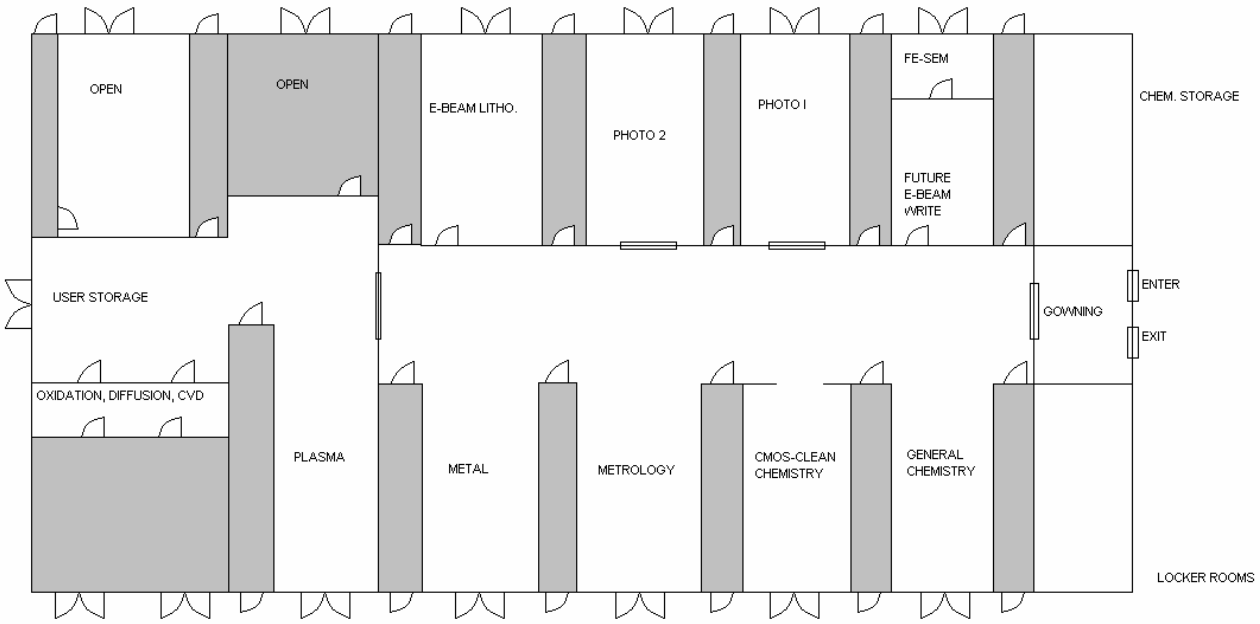
Medical emergencies such as chemical burns, inhalation injuries, falls, heart attacks, etc. require you to contact the NIST Fire Protection Group at x2222. If you are wearing the personal safety device, you may activate this device in the event of a medical emergency.

8. Contacts

8.1 Staff Directory

Robert Celotta…….Director ……...301-975-3710
Gerard Henein…….....Nanofab Manager……..301-975-5645
Russ Hajdaj……Nanofab Asst. Manager/Safety Coordinator……...301-975-2699
Marc Cangemi…….Process Engineer……301-975-5993
James Owen..... Technician.....301-975-5623
Larry Buck.....Technician.....301-975-2242
Dennis Myers.....Safety Committee.....301-975-5823
Mike Blackmon……...Safety Committee……..301-975-5822

9. Facility Layout



10. Incident report form

NIST CNST Nanofab

Incident Report Form

To be completed by the facility user immediately after an incident involving equipment, facilities, other users, and/or safety related problems. This form is to be returned to the Facility Manager or respective Staff Member upon completion. This is not an accident report form. This form is an information collection form that will assist facility staff in making an accurate assessment of what occurred, and the appropriate corrective actions that must be taken.

Date: _____ Time: _____

Name: _____ Extension: _____

State fully how this incident occurred:

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11. Appendix:

NIST Chemical Labeling Instructions:

CHEMICAL CONTAINER LABELING

1. PURPOSE

The purpose of this Health and Safety Instruction (HSI)* is to provide guidance for proper labeling of all chemical containers in the NIST. Although emphasis is placed on container labeling in labs, this HSI is equally applicable to all work areas and storage areas within the NIST, including those managed, operated, or used by NIST support/service units. Proper labeling will permit a person to quickly assess potential hazards and handling precautions, and to identify the owner of chemical substances in the workplace. This will facilitate safe handling, use, and disposal of chemicals in the NIST and benefit lab workers, safety representatives, support/service staff, and rescue personnel.

* Acronyms used herein are defined at the end of this document.

2. ACKNOWLEDGEMENT

The NIST labeling system for chemical containers is adapted from the system developed and implemented by the Dow Chemical Company's Central Research Laboratory in Midland, Michigan (Dr. Eric E. Bancroft, the former Manager of Safety and Regulatory Affairs, facilitated this adaptation). The NIST chemical inventory system and multipurpose lab door sign are of NIST origin.

3. INTRODUCTION

The OSHA Hazard Communication Standard (29CFR1910.1200) and Occupational Exposure to Hazardous Chemicals in Laboratories Standard (29CFR1910.1450) require that all workers be apprised of the hazards of the chemicals in their workplaces through the use of a written Hazard Communication Program, a written Chemical Hygiene Plan, proper labeling of containers, use of Material Safety Data Sheets (MSDSs), and appropriate training. HSI 7 documents NIST's Hazard Communication Program and NIST's Chemical Hygiene Plan is given in HSI 20. This HSI (15) specifies the procedures to be followed by all NIST lab workers (employees, guest researchers, research associates, faculty and intergovernmental appointees, contractors, students, etc.) and support/service staff to comply with the labeling requirements of the Hazard Communication Standard, and to promote safe handling of chemicals in our workplace as a result of clear communication of potential hazards. The procedures outlined herein also help satisfy certain regulations promulgated by the EPA. Every effort has been made to simplify this labeling procedure while retaining essential label data. A labeling guide is provided to facilitate the labeling task.

4. SCOPE

This HSI applies uniformly to all NIST labs, work areas, and storage areas in Gaithersburg and Boulder as specified below:

- chemical substances in all forms (liquids, gases, solids, and mixtures thereof) and conditions (new, old, excess, diluted, used, spent, waste, synthesized, samples, etc.) are covered by this HSI;
- small quantities (such as those found in ordinary households) of properly labeled consumer products such as paints, dishwashing detergents, hand cleaning agents, bathroom cleaners, window cleaners, video-monitor screen cleaners, plant fertilizers, insecticides, furniture polish, etc., are not covered by this HSI--the vendor's label is adequate or a plain white label can be used (as needed) to identify such materials;
- personal consumption items (foods, beverages, medicines, cosmetics, and tobacco products) are not covered;
- process vessels and reactors that have readily accessible alternate written documentation are not covered;
- containers of chemicals (other than hazardous wastes) being shipped off NIST grounds are not covered (contact the NIST/MASC Shipping and Receiving Office for assistance with such shipments and to ensure compliance with all applicable regulations);
- hazardous waste shipping containers, used by the NIST/MASC Safety Office to ship hazardous waste off NIST grounds, are not covered;

- all other chemical containers, compressed gas cylinders and liquefied gas containers, stored or used in the NIST, are covered by this HSI and must be properly labeled.

5. IMPLEMENTATION

The labeling procedures outlined herein are effective with the issue of this HSI and all containers not excepted in item (4) above, must be labeled by the owner when received, used, or retrieved from storage, whichever comes first. Regardless of origin of the chemical substance (i.e., chemicals obtained from the NIST/MASC storeroom, procured directly from the manufacturer, borrowed or transferred from another NIST lab worker or collaborator external to the NIST, synthesized in an NIST lab or a lab external to NIST, etc.), all of these containers must be labeled in accordance with this HSI.

6. PROCEDURES

Detailed labeling procedures are described in the following paragraphs.

6.1 *Label Data*. All NIST labels must include the following information:

- common chemical name (not formulae), written in English so that it is easily recognized,
- an appropriate signal word, e.g.,"DANGER," "WARNING," or "CAUTION,"
- potential hazards, e.g., the hazards due to flammability, reactivity, or toxicity,
- owner's (responsible person's) last name, and
- the date the container is received or filled.

If label space permits, the label should include:

- specific precautions to avoid injury in handling, e.g., "avoid inhalation," "avoid contact with skin," "avoid open flames,"
- first-aid instructions, as stated in the appropriate MSDS or its equivalent, and
- any known chronic (long-term) or delayed health effects and unusual or special hazards.

The new NIST labeling system has been designed to include this required information using color-coded labels, in convenient assorted sizes, made available through the NIST/MASC storeroom. All containers in NIST labs and work areas requiring labels (as specified in item (4) herein) shall be labeled with these printed color-coded stick-on labels. NIST labels are shown in Table 1a.

6.2 *Label Format*. The NIST label format facilitates hazard assessment and classification by linking color-coded labels to a color-coded Labeling Guide (see table 1b). The relationship between hazard level, signal word, color code, etc., is given in table 2. The hazard classification (high, low, etc.) and selection of a corresponding colored label (red, yellow, etc.) will be based upon the relative level of potential hazard in each of three hazard categories (flammability, reactivity, and health) for each substance. Each container will be labeled according to the most severe potential hazard in any one of the three categories. For example, a substance with relative potential hazard levels of high (red) for flammability, low (yellow) for reactivity, and very low (green) for health, would be labeled with a red label. The relative levels of potential hazards will be indicated on the NIST label by correctly marking the checkboxes provided thereon. Health hazards are subdivided into four subcategories--skin absorption, inhalation, ingestion, and eye/skin contact--and each is to be assessed on the NIST label (see table 1a). The proper hazard classification and label color will be determined by using the appropriate MSDS (or its equivalent) and the NIST Labeling Guide. Note that the NIST color-coded labeling system is designed to identify and communicate potential hazards, and is not to be confused with color-coding systems used by some manufacturers to identify specific corrosives or to designate safe storage practices. For example, an acid and a solvent may both bear red NIST labels (red for acid reactivity and red for solvent flammability) but must be stored separately. Also, the NFPA diamond (with or without color-coding), if used on the manufacturer's label to indicate potential hazards of the chemical substance under fire conditions, may show different hazard ratings than those of the manufacturer for storage and general lab use.

6.3 *Labeling Newly Acquired Chemicals and Chemicals Prepared in the Lab*. This section applies to all substances newly acquired and/or prepared in the lab, and includes those purchased, synthesized, mixed, or transferred from one container to another. Every lab worker should know the flammability, reactivity, and health hazards associated with each chemical substance used in the lab, and how to classify the potential hazards of each chemical. Where available, the Material Safety Data Sheet (MSDS) must be used, along with the NIST Labeling Guide, to classify each chemical substance and ensure that it is properly labeled. Chemicals purchased from the NIST/MASC storeroom or from an outside vendor and bearing the manufacturer's label must be classified using the NIST Labeling Guide. In those cases where the manufacturer's label contains sufficient information to meet NIST requirements, the MSDS and Labeling Guide will be used to classify the substance/compound, and the new owner can simply attach the appropriate color-coded "Owner and Date" label (see table 1a). If the manufacturer's label is inadequate, it must be supplemented with an NIST color-coded label that is filled out using an MSDS and the Labeling Guide. The vendor labels must not be removed, defaced, or partially or totally obscured by NIST labels.

Chemicals prepared for use or research in the lab (e.g., synthesized, mixed, or transferred from other containers), must bear an appropriate NIST label, selected by classifying the potential hazards of the substance using the appropriate MSDS(s) and the Labeling Guide. The proper label (red, orange, yellow, etc.) is chosen by determining the single most severe potential hazard when collectively considering the flammability, reactivity, and health hazards in accordance with the Labeling Guide.

Common property lab containers that are regularly filled with stock chemicals (such as safety cans and squeeze bottles) must bear an appropriate NIST label. Squeeze bottles approved by the NIST/MASC Safety Office, and bearing an embossed (or stenciled) chemical name and NFPA hazard designation do not require use of the NIST label.

Sample containers, of similar substances, that are too small for normal size labels may be collectively labeled by placing them in a secondary container bearing an appropriate NIST label. Nonsimilar small samples must be individually labeled by placing them in a secondary container with an appropriate label affixed. No matter how small, and even though placed in a properly labeled secondary container, sample containers must bear labels indicating the compound name. The individual labels on small samples, held in a properly labeled secondary container, may contain an identification number in addition to the compound name. The identification number may be used by the lab worker to trace the origin of the sample to a particular logbook or notebook. Use of an identification number by the lab worker does not relax the NIST requirements to fully identify the sample hazards on the label affixed to the secondary container. It is strongly recommended that sample containers be large enough to support an NIST colored label (wherever possible).

Labels are not required for samples prepared for "immediate use" and subsequent disposal. "Immediate use" means that the substance will be under the control of and used only by the person who prepares it or transfers it from a labeled container and only within the work shift in which it is prepared or transferred. If such samples are left unattended, they must be labeled in accordance with this HSI.

When potential hazard data are not available, chemical substances must be labeled with the NIST red-stripe "UNKNOWN HAZARDS" label until reliable data are obtained (e.g., from an MSDS).

If a mixture of chemical substances has been tested, as a whole, to determine the hazards of the mixture, the results of such testing will be used to classify (and label) the mixture according to the Labeling Guide. Mixtures that have not been tested as a whole for health hazards shall be assumed to present the same health hazards as any hazardous chemical that comprises one percent or more of the total weight or volume of the mixture, or any carcinogen or potential carcinogen that constitutes 0.1 percent or more of the total weight or volume of the mixture. If a hazardous component constitutes less than one percent (or less than 0.1 percent for a carcinogen) of a mixture, the entire mixture shall be assumed to present the same hazard as the component if the component could be released in concentrations which

- would exceed an established OSHA permissible exposure limit (PEL), or
- would exceed an ACGIH threshold limit value (TLV), or
- could present a health hazard to workers in those concentrations.

The presence of certain hazardous components in mixtures, even in dilute concentrations (less than 1 mg/liter), requires that a minimal hazard classification be assigned to such mixtures. The minimal hazard level is "Low" (as indicated by a yellow NIST "CAUTION" label or a yellow NIST "Owner and Date" label) for all mixtures that contain: a known or suspect carcinogen; or a toxic chemical that is EPA-regulated at concentrations which exceed a specific dilute level. Thus, no container should bear a green NIST "PRECAUTIONARY LABELING NOT REQUIRED" label or a green NIST "Owner and Date" label if it contains such substances, even in dilute concentrations (less than 1 ppm or 1 mg/liter). This minimal hazard level rule, for mixtures containing carcinogens and specific toxic chemicals, applies

uniformly to the labeling of new, used, or waste chemicals. In addition, waste chemicals that contain any EPA-listed hazardous waste (in any concentration) must be labeled in accordance with this minimal hazard level rule. The Safety Office maintains current lists of these regulated substances.

An untested mixture of flammable (or combustible) liquids is assumed to present the same flammability hazards as its most hazardous component(s), unless 99 volume percent (or more) of the mixture is comprised of components that are classified as less hazardous in accordance with the NIST Labeling Guide.

Any project that involves the generation, use, handling, or storage of a biohazardous or radioactive agent, must be reviewed and cleared by appropriate NIST/MASC safety personnel before the project can be initiated. Labeling and handling precautions for these substances, in all concentrations, will be established during the clearance procedure. Projects involving radioactive agents must be authorized by Health Physics (x5800 in Gaithersburg) or the MASC Safety Office (x7285 in Boulder). Projects involving biohazardous agents must be approved by the NIST/MASC Industrial Hygienist (x5821 in Gaithersburg or x3912 in Boulder).

6.4 *Labeling Used or Waste Chemicals*. This section covers the labeling of all chemical substances, requiring labeling as defined in item (4), and not covered in item (6.3); for example, used but still useful chemicals (partially spent, unspent but diluted or contaminated, partially reclaimed, etc.) and waste chemicals (spent or declared as no longer useful by the lab worker). Each container (for used or waste chemicals) will be clearly labeled by checking appropriate boxes on the labels shown in table 1a and by using the procedures described in item (6.3).

If the used or waste chemical substance/compound is unchanged (chemical structure unaltered), label selection is simplified. In this case, the hazard level (and proper label color) is easily selected by simply noting the label colors on the source chemical containers and taking the worst case (highest hazard level) and checking the proper boxes on the NIST labels to coincide with those on the source containers. If the used or waste compound has been chemically altered, the new compound(s) must be classified as detailed in item (6.3). Hazard classification and label color selection for mixtures of used or waste chemicals will be performed as outlined in item (6.3).

Chemicals that are no longer useful to the lab worker, and chemical waste, are collected by the NIST/OHSD/Environmental Compliance Group (MASC Safety Office in Boulder) for disposal (see HSI 16). Pickup of these materials is arranged by electronically submitting a ChemWaste Pickup Request in Gaithersburg or calling the MASC Safety Office (x7285 or 3064) in Boulder. The NIST/OHSD/ECG (MASC Safety Office in Boulder) will transfer excess vendor-labeled chemicals to other lab workers or declare them to be waste and properly dispose of them. Used chemicals are to be properly labeled and stored in the lab until they are declared as waste by the lab worker, and like all other waste chemicals are disposed of as indicated above. When a used or an unused chemical (vendor or NIST labeled) is no longer needed and is declared as waste, it is automatically classified as a "hazardous waste" under current regulations. Similarly, when the accumulation limit is reached in a chemical waste container, the contents are automatically classified as "hazardous waste." These "hazardous wastes" must be properly identified as "Hazardous Waste for Pickup" and promptly removed from the lab. It is mandatory that the lab worker immediately arrange for Pickup Service to remove these materials (i.e., electronically submit a ChemWaste Pickup Request in Gaithersburg; call the MASC Safety Office in Boulder). The appropriate NIST/MASC personnel will then assume responsibility for compliance with applicable regulations on additional labeling, transporting, and disposing of the used or waste substance. Hazardous waste may be temporarily stored in a safe location within the lab until it is picked up, and shall not (at any time) be placed in the corridors.

The maximum allowable container size for hazardous waste is 5 gallons. Use of this container size requires the use of metal or plastic safety cans (or approved disposal cans) and the approval of the NIST/OHSD/ECG or the MASC Safety Office. Generally, hazardous waste will be stored in compatible containers not exceeding 2.5-gallon capacity. Acute hazardous waste containers must not exceed 1-quart capacity. Lists of acute hazardous wastes are available in the NIST/OHSD/ECG and the MASC Safety Office. Flammable and combustible liquids (new, excess, used, or waste) are restricted to the container capacities designated in table 3. If a flammable or combustible liquid is also acutely hazardous, the waste container must not exceed 1-quart capacity--again, the most severe restriction governs. Adequate ullage volume (head space) must be maintained in filling all waste containers. An ullage allowance of 10% of container volume is recommended. Thin wall polyethylene bottles are not to be used for waste containing nonpolar organic liquids because these liquids readily permeate polyethylene. Halogenated and nonhalogenated solvents should be separated to reduce recycling costs.

Excess chemicals are to be presented for disposal in their closed, compatible, original containers (vendor or NIST labeled) with all labels intact and legible; however, they are to be prepared for Pickup Service by packaging them in a suitable box (cardboard, plastic, wood) or pail (plastic or metal) and marking "Hazardous Waste for Pickup" on the box (or pail). Cardboard boxes are preferred packing cartons. Packaging must be sufficient to prevent breakage or spillage

in normal handling and transport, waste substances packed in the same box must be compatible, and the gross weight of the package is not to exceed 50 pounds. A packing list must be provided by the lab worker for all chemical waste picked up. In Gaithersburg, the packing slip simply lists the substance and its purity and quantity in each container, as this information is coupled with a copy of the electronically submitted ChemWaste Pickup Request. In Boulder, the MASC Chemical Waste Disposal Request Form must be filled out and used as the packing list to accompany waste containers picked up. For some substances, the NIST/OHSD/ECG or MASC Safety Office may require the owner to furnish an MSDS at the time of pickup.

Used or waste chemicals are to be temporarily stored in closed, compatible containers (e.g., safety-coated glass bottles, plastic bottles, or metal cans) and must be properly labeled using the labels shown in table 1a. The procedure for disposing of used or waste chemicals is the same as that for excess (unused) chemicals as described above. No waste materials will be accepted by the NIST/MASC Pickup Service unless fully identified by vendor labels or NIST labels (properly and completely filled out).

The estimated composition of mixtures of waste chemicals must be known and fully disclosed to the Safety Office when the waste is picked up. The presence of regulated substances in the waste, even in minute concentrations (less than 1 ppm or 1 mg/liter), must always be revealed because special disposal procedures are required for such substances. The low-level presence of regulated substances in used or waste chemicals does not affect container label selection beyond the labeling procedures outlined in item (6.3). The vendor's current MSDS should alert the user when a chemical is regulated by federal law, and the Safety Office maintains lists of substances currently regulated by local, state, and federal laws.

Where mixtures of used or waste substances are involved, the supplementary "Contents" label shown in table 1a may be used to fully disclose the composition (quantities and estimated purities of the mixture components) of the container contents--dates are not needed for this application of the "Contents" label [see item (6.8)]. Alternatively, the information provided by the "Contents" label may be supplied to the Pickup Service as hard-copy and securely attached to the appropriate container without damaging the NIST color-coded labels thereon.

Materials of a particularly hazardous or incompatible nature will not be mixed with other materials, but will be stored in individual containers. Highly toxic, carcinogenic, biologically active, or otherwise very harmful chemicals must be properly inventoried, labeled, and packaged prior to disposal in approved and controlled containers. For further guidance concerning packaging of hazardous waste for disposal, see HSI 16. Additional information on certain classes of regulated substances may be found in HSI 10 (carcinogens), HSI 18/18B(asbestos), and HSI 16 (polychlorinated biphenyls). HSI 19 deals with hazardous biological agents and biosafety.

The lab worker is reminded that mixing of any used or waste substances is discouraged. If such substances are to be mixed in the same container, be sure they are compatible before mixing, and if in doubt use separate containers.

6.5 *Chemical Inventory*. The NIST labeling system is closely tied to the NIST inventory system. An inventory of chemical substances stored in the lab must be performed at least once per year. Significant changes in inventories at any time throughout the year are to be documented by updating the inventory list. Inventory listings are to be maintained by each division. Copies of updated inventory listings are to be submitted (at least annually) to the NIST/MASC Safety Office using a standardized data base format on floppy disks. Formal requests will be issued each fall for these NIST-wide inventory updates that are to be completed by the end of the calendar year. Table 4 (a reproduction of NIST Form 1255) shows the inventory data base structure. To ensure compliance with applicable regulations (labeling, handling, inventories, and disposal), each acquisition of a chemical new to a particular lab or work area is to be recorded by completing an inventory form (NIST-1255), attaching it to a copy of the vendor's MSDS, and forwarding to the NIST/MASC Safety Office. This procedure is not necessary for replacement of existing stock. Copies of the 1255s (sent to the Safety Office) should be retained in each division office to facilitate updating of division inventory files by each division during the annual chemical inventory update.

When the inventory is updated (at least annually) the list is to be reviewed by the person(s) responsible for the lab and the primary hazardous substances are to be selected and listed on the multipurpose door sign [see item (6.6)]. This "short list" of the most hazardous substances in the lab should be determined on the basis of relative hazard and quantity of substance stored. This is the only inventory list that must be posted at the lab entrance.

6.6 *Multipurpose Door Sign for Labs*. A blank NIST multipurpose door sign is shown in table 1c. It is recommended that a typewriter or an extra fine point permanent-marker pen (available in the NIST/MASC storeroom) be used to prepare this door sign. Checkboxes are used to designate the requirements for safety glasses, and whether food and drink are allowed. The most hazardous substances stored in the lab are then selected (by review of a recently updated inventory) and listed on the door sign. This primary hazardous substance list will show substance/compound name and

typical quantity on hand. Conventional emergency contact information is to be supplied on the bottom portion of the door sign. If the lab worker prefers not to post their out-of-hours phone number on the door sign, it may be given to the NIST Security Office and the door sign prepared as follows: in Gaithersburg, enter Crit. Exper." (an abbreviation for Critical Experiment List) as the out-of-hours phone number; in Boulder, enter the Security Office phone number (x3530) as the out-of-hours phone number. If the lab worker does not want to release their out-of-hours phone number at all, another contact should be selected. The division chief's signature and date signifies his (her) concurrence with the hazard assessments and safety measures posted for each lab. These signs, if kept current, will aid emergency response teams (responding to fires, spills, etc.) and serve as a useful reminder of potential hazards in the lab for our staff and visitors alike.

In some cases, other door signs, in addition to the multipurpose door sign, will also be required, e.g., where certain radioactive, high voltage, biological, or laser experiments are performed, safety shoes are required, hard hats are required, etc.

6.7 *Labeling Chemicals with Limited Shelf Life*. All substances that have a limited shelf life must be stored in containers with labels that show date of acquisition, date when first opened, and the discard date. Peroxidizable compounds must be labeled and monitored in accordance with HSI 6. Lab workers (and line supervisors) shall devise their own monitoring system (as needed) to comply with the special requirements of HSI 6. The labeling requirements of HSI 6 are met by using the NIST "PEROXIDIZABLE COMPOUND" label as shown in table 1a. This special label is to be used, as appropriate, on containers bearing vendor and/or NIST hazard communication labels.

6.8 *Special Labels*. The "PEROXIDIZABLE COMPOUND" label is considered a special label. Other special labels (all stick-ons) supplied by NIST include the "CANCER-SUSPECT AGENT" and "KNOWN CANCER AGENT" labels for carcinogenic substances, the "Owner and Date" color-coded labels, and the supplemental "Contents" label (see table 1a).

The carcinogen labels are to be affixed to all containers of carcinogenic substances without obscuring any other label information. These carcinogen labels are to be used, as appropriate, on containers bearing vendor and/or NIST labels. The "Owner and Date" labels are to be used only on containers bearing vendor labels and on compressed gas cylinders and liquefied gas containers. In addition, both compressed gas cylinders and liquefied gas containers must bear some legible marking, tag, or label to clearly indicate their contents (e.g., hydrogen, fluorine, propane, etc.).

The supplemental "Contents" label (black and white) serves two purposes. It may be used, at the lab workers discretion, and where container size permits, as a companion label to the NIST color-coded labels to fully describe container contents. Alternatively, a logbook may be used to maintain records of container contents where NIST color-coded labels do not provide sufficient space to list the container contents. The "Contents" label may also be used, along with a required permanent-record logbook, to maintain inventory control records for specific regulated substances (e.g., carcinogens, radioactive agents, and toxic chemicals that are regulated at designated concentration levels) and for biohazardous agents. If used for this continuous inventory control of such substances, as a convenience to the lab worker, the "Contents" label (and the log book) will show substance, purity, and the dates and quantities of incremental additions to (or removals from) the container. A checkbox is provided on the "Contents" label to indicate its special (and optional) use for inventory control.

6.9 *Filling out NIST Labels*. The NIST Labeling Guide (table 1b) provides a quick reference to the criteria used to classify potential hazards of chemical substances and to select the appropriate label. Use of the appropriate MSDS, provided by the manufacturer of the specific substance/compound, will be required to properly complete NIST printed labels. The format of the MSDS varies from one manufacturer to another, but all are required to describe the potential hazards of a specific chemical substance in each of the major categories of flammability, reactivity, and health. By extracting data from the MSDS and applying it to the Labeling Guide, the proper label color can be determined and appropriate hazard-level boxes checked on the NIST label. Check the "MSDS? [] Yes" box on the label when the MSDS is available and used to select and fill out the label. If a reliable source, other than the manufacturer's MSDS, is used to classify (or help classify) the potential hazards of a chemical substance, identify the source in the "Ref." blank on the NIST label. The "Ref." blank can also be used to cite the logbook wherein additional information may be found.

It is important to note that the Labeling Guide is based on acute (short term exposure and health effects) rather than chronic (long term exposure and health effects) health hazard criteria. Delayed (chronic) health hazards should be noted in the "OTHER HAZARDS" blank on the NIST label. The Labeling Guide uses the flash point as the only criterion for "FLAMMABILITY" hazard classification. "REACTIVITY" and HEALTH HAZARDS" are generally more difficult to assess and in some cases require careful coupling of the MSDS and the Labeling Guide. The toxicity limits and other health hazard criteria, given in the Labeling Guide and in table 5, are based on animal test data (see table 5 for details). Note that the "Eye/Skin Contact" category addresses the hazards associated with corrosives and

irritants and is based on animal test data. Epidemiological studies and case reports of adverse health effects in exposed human populations shall be considered in classifying all health hazards, when such data are available.

Many manufacturers use the NFPA hazard rating system. Many MSDSs will list these hazard ratings and CERCLA (EPA) hazard ratings when they are known. The NFPA ratings must be used with some caution as they are based on potential hazards under fire conditions. The CERCLA hazard ratings are based on the NFPA hazard ratings and are identical at the 0, 1, 2, and 3 levels, and differ only for NFPA ratings of 4 which are also given a CERCLA rating of 3. The CERCLA ratings also include a hazard category for "persistence" of hazardous substances in the environment. This category (for biodegradability) is not addressed in the NFPA hazard rating system or in the NIST labeling system. The NFPA and CERCLA ratings do provide reasonable guidance in assessing hazards in the absence of detailed information from an MSDS. To minimize confusion and facilitate hazard classification, cross-references to hazard codes are included in table 5. This table links the NIST label system to the NFPA and CERCLA hazard rating systems.

If hazard classification cannot be determined using the MSDS (or equivalent) and the Labeling Guide (or table 5), do not guess or attempt to estimate the potential hazards, use the NIST "UNKNOWN HAZARDS" label. Use the "MP/BP" blank on this label to show the melting point and boiling point of the substance, if known.

6.10 *Summary of Proper Labeling Procedures*. Be serious about labeling of chemical containers. It is your responsibility and will promote safe handling of chemicals in the lab for yourself and your fellow worker. In addition, it is a highly regulated activity and is compulsory, not optional. Use the common chemical names on labels (not formulas, structures, or abbreviated names). If an MSDS is available, the name on the label must be exactly the same as the name on the MSDS. Don't guess at hazard classification of chemicals. Obtain an MSDS (or equivalent) and use it to determine the level of potential hazards (and to fill out labels) by referring to the NIST Labeling Guide. Complete all label fields, check all appropriate boxes, and completely fill out each and every label.

7. DEFINITIONS AND ACRONYMS

ACGIH - American Conference of Governmental Industrial Hygienists.

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act (Superfund): implemented by the U.S. Environmental Protection Agency (EPA).

CFR - U.S. Code of Federal Regulations.

EPA - U.S. Environmental Protection Agency.

HSI - Health and Safety Instruction, issued by the Occupational Health and Safety (OHS) Division of the NIST, U.S. Department of Commerce. Note: HSIs will be used to update and replace all SPGs (Safety Program Guides) previously issued by the NIST. "HSI" and "SPG" will be used interchangeably until all SPGs have been replaced.

LC_{50} - The Median Lethal Concentration of a substance, administered by continuous inhalation in a prescribed manner for a given period of time, that is most likely to kill 50% of a group of animals within a specified time under test conditions. Specific terms and values are given in table 5.

LD_{50} - The Median Lethal Dose of a substance, administered orally or by continuous contact in a prescribed manner for a given period of time, that is most likely to kill 50% of a group of animals within a specified time under test conditions. Specific terms and values are given in table 5.

MASC - Mountain Administrative Support Center, U.S. Department of Commerce.

MSDS - Material Safety Data Sheet.

NIST - National Institute of Standards and Technology, U.S. Department of Commerce.

NFPA - National Fire Protection Association.

OSHA - Occupational Safety and Health Administration, U.S. Department of Labor.

PEL - The Permissible Exposure Limits established by OSHA, specifying allowable concentrations of air contaminants in the work environment. PELs may be given as a person's average exposure--a Time Weighted Average (TWA)--to airborne contaminants in any 8-hour workshift of a 40-hour workweek, or as ceiling values that are not to be exceeded.

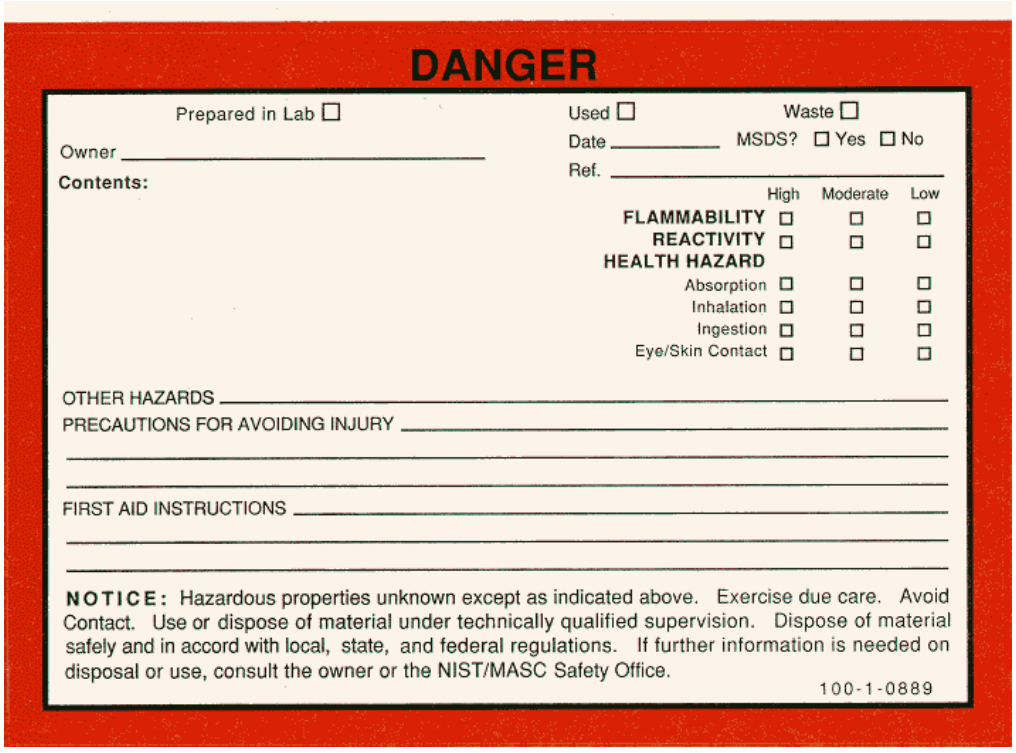
PELs are expressed as ppm (by volume) of vapor or gas in air, or as mg of chemical substance per cubic meter of air. Standards are given in 29CFR1910.1000, Subpart Z.

PLNR - PRECAUTIONARY LABELING NOT REQUIRED: signal words on the green NIST label.

SCF - Standard Cubic Feet, the volume occupied by a gas at 1-atmosphere pressure and 21.1°C (70°F).

TLV - The Threshold Limit Values established by the ACGIH, recommending allowable concentrations of airborne contaminants for avoidance of adverse health effects. TLVs may be given as a Time Weighted Average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek, as a Short Term Exposure Limit (STEL) which is the maximum 15-minute TWA concentration allowed, or as a ceiling concentration that should not be exceeded during a workshift. TLVs are expressed in the same units as PELs. TLVs are listed in the ACGIH booklet entitled "Threshold Limit Values and Biological Exposure Indices," Cincinnati, Ohio (updated annually).

Table 1a. NIST Labeling System: Labels for Containers



CAUTION

Prepared in Lab ☐ Used ☐ Waste ☐

Owner _____ Date _____ MSDS? ☐ Yes ☐ No

Contents: Ref. _____

	Low
FLAMMABILITY	☐
REACTIVITY	☐
HEALTH HAZARD	
Absorption	☐
Inhalation	☐
Ingestion	☐
Eye/Skin Contact	☐

OTHER HAZARDS _____

PRECAUTIONS FOR AVOIDING INJURY _____

FIRST AID INSTRUCTIONS _____

NOTICE: Hazardous properties unknown except as indicated above. Exercise due care. Avoid Contact. Use or dispose of material under technically qualified supervision. Dispose of material safely and in accord with local, state, and federal regulations. If further information is needed on disposal or use, consult the owner or the NIST/MASC Safety Office.

100-3-0889

WARNING

Prepared in Lab ☐ Used ☐ Waste ☐

Owner _____ Date _____ MSDS? ☐ Yes ☐ No

Contents: Ref. _____

	Moderate	Low
FLAMMABILITY	☐	☐
REACTIVITY	☐	☐
HEALTH HAZARD		
Absorption	☐	☐
Inhalation	☐	☐
Ingestion	☐	☐
Eye/Skin Contact	☐	☐

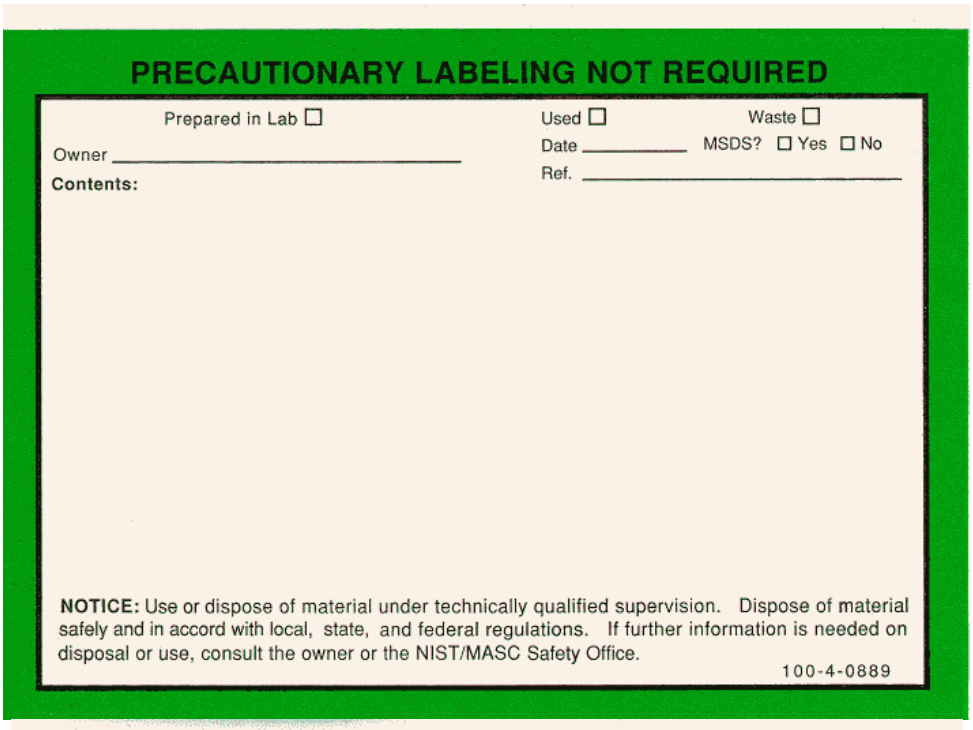
OTHER HAZARDS _____

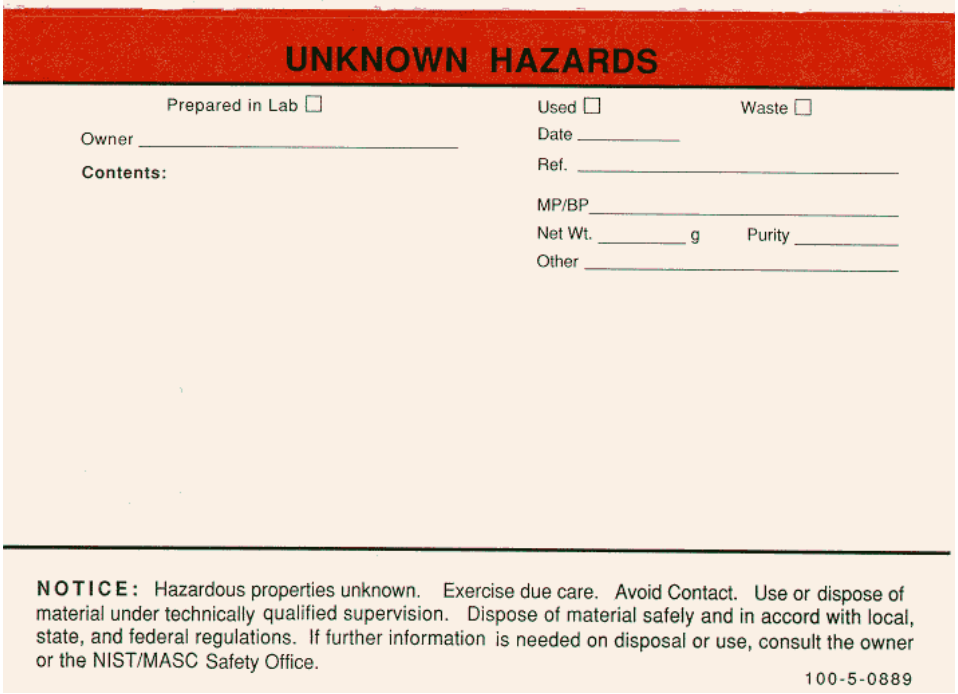
PRECAUTIONS FOR AVOIDING INJURY _____

FIRST AID INSTRUCTIONS _____

NOTICE: Hazardous properties unknown except as indicated above. Exercise due care. Avoid Contact. Use or dispose of material under technically qualified supervision. Dispose of material safely and in accord with local, state, and federal regulations. If further information is needed on disposal or use, consult the owner or the NIST/MASC Safety Office.

100-2-0889


PRECAUTIONARY LABELING NOT REQUIRED
Prepared in Lab ☐
Used ☐
Waste ☐
Owner
Date
MSDS? ☐ Yes ☐ No
Ref.
Contents:
NOTICE: Use or dispose of material under technically qualified supervision. Dispose of material safely and in accord with local, state, and federal regulations. If further information is needed on disposal or use, consult the owner or the NIST/MASC Safety Office.
100-4-0889


UNKNOWN HAZARDS
Prepared in Lab ☐
Used ☐
Waste ☐
Owner
Date
Ref.
Contents:
MP/BP
Net Wt. g
Purity
Other
NOTICE: Hazardous properties unknown. Exercise due care. Avoid Contact. Use or dispose of material under technically qualified supervision. Dispose of material safely and in accord with local, state, and federal regulations. If further information is needed on disposal or use, consult the owner or the NIST/MASC Safety Office.
100-5-0889

Contents

Substance	Quantity	Purity	Date
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

☐ Inventory Control Required Container No. _____

100-51-0889

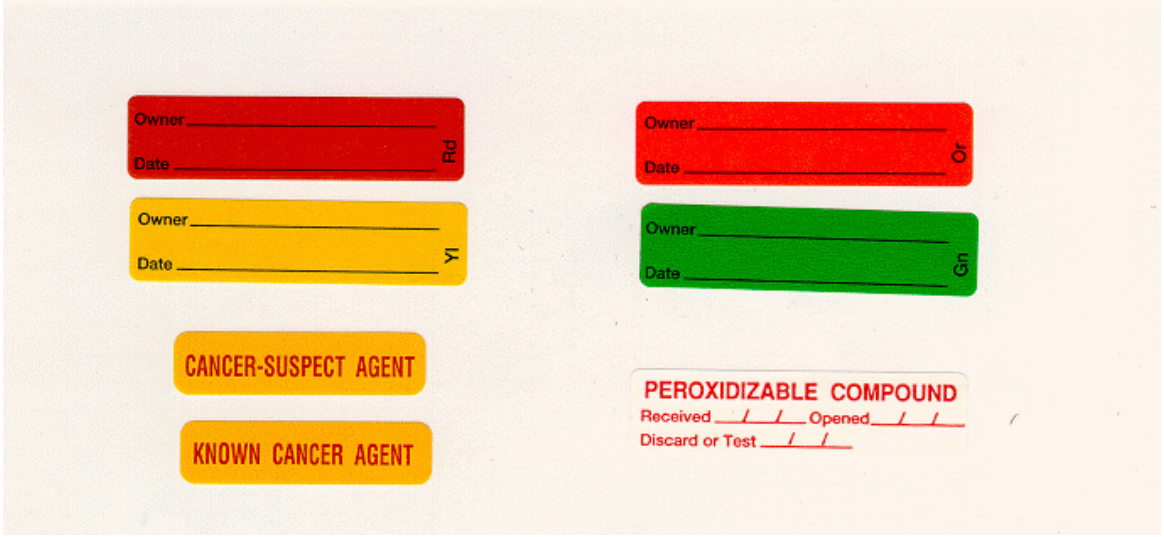
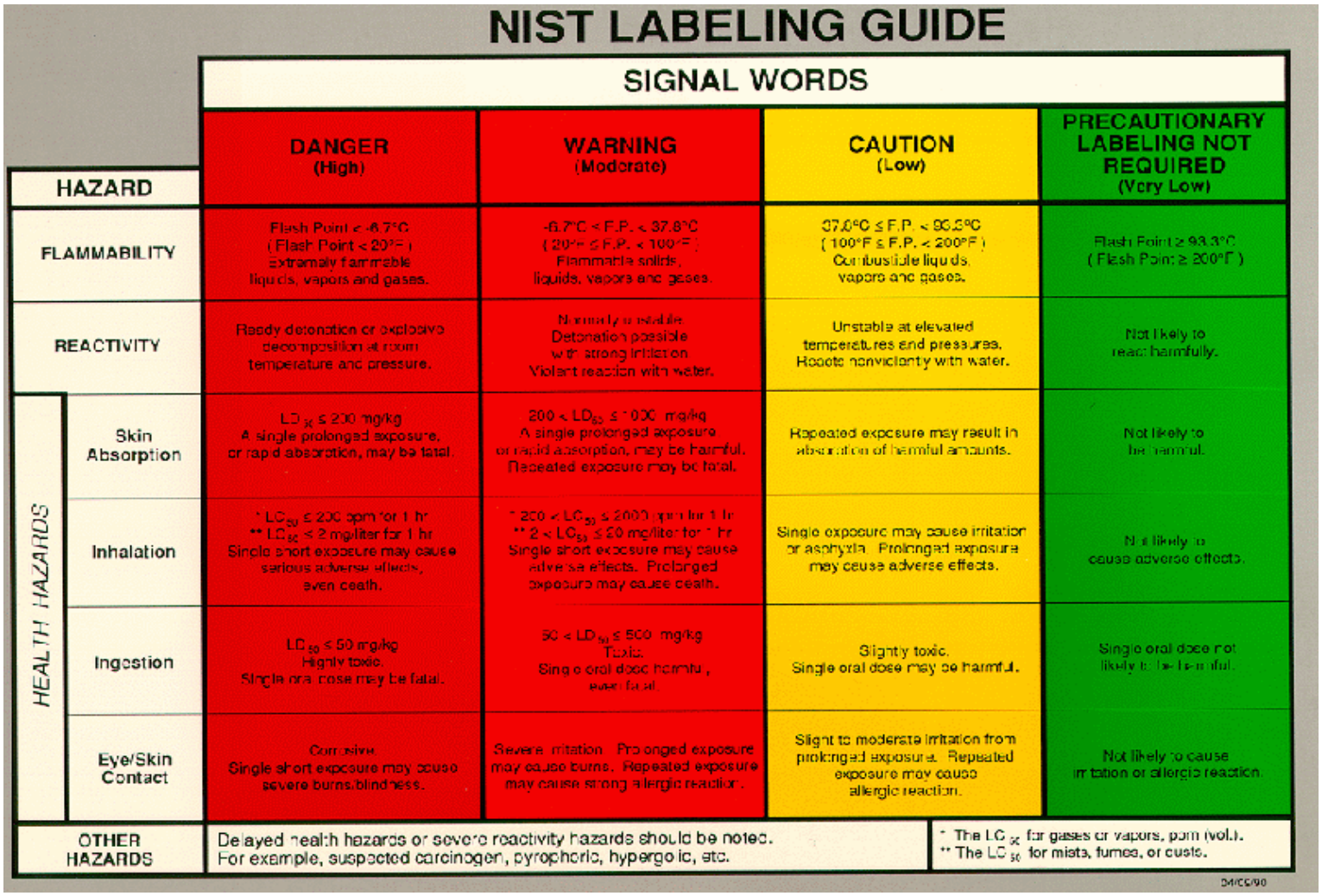


Table 1b. NIST Labeling System: NIST Labeling Guide



NIST LABELING GUIDE

HAZARD		SIGNAL WORDS: DANGER (High)	WARNING (Moderate)	CAUTION (Low)	PRECAUTIONARY LABELING NOT REQUIRED (Very Low)
FLAMMABILITY		Flash Point < -6.7°C (Flash Point < 20°F) Extremely flammable liquids, vapors and gases.	-6.7°C ≤ F.P. < 37.8°C (20°F ≤ F.P. < 100°F) Flammable solids, liquids, vapors and gases.	37.8°C ≤ F.P. ≤ 93.3°C (100°F ≤ F.P. ≤ 200°F) Combustible liquids, vapors and gases.	Flash Point ≥ 93.3°C (Flash Point ≥ 200°F)
REACTIVITY		Ready detonation or explosive decomposition at room temperature and pressure.	Normally unstable. Detonation possible with strong initiation. Violent reaction with water.	Unstable at elevated temperatures and pressures. Reacts nonviolently with water.	Not likely to react harmfully.
HEALTH HAZARDS	Skin Absorption	LD_{50} ≤ 200 mg/kg A single prolonged exposure, or rapid absorption, may be fatal.	200 < LD_{50} ≤ 1000 mg/kg A single prolonged exposure or rapid absorption, may be harmful. Repeated exposure may be fatal.	Repeated exposure may result in absorption of harmful amounts.	Not likely to be harmful.
	Inhalation	* LC_{50} ≤ 200 ppm for 1 hr ** LC_{50} ≤ 2 mg/liter for 1 hr Single short exposure may cause serious adverse effects, even death.	* 200 < LC_{50} ≤ 2000 ppm for 1 hr ** 2 < LC_{50} ≤ 20 mg/liter for 1 hr Single short exposure may cause adverse effects. Prolonged exposure may cause death.	Single exposure may cause irritation or asphyxia. Prolonged exposure may cause adverse effects.	Not likely to cause adverse effects.
	Ingestion	LD_{50} ≤ 50 mg/kg Highly toxic. Single oral dose may be fatal.	50 < LD_{50} ≤ 500 mg/kg Toxic. Single oral dose harmful,	Slightly toxic. Single oral dose may be harmful.	Single oral dose not likely to be harmful.
	Eye/Skin Contact	Corrosive. Single short exposure may cause severe burns/blindness.	Severe irritation. Prolonged exposure may cause burns. Repeated exposure may cause strong allergic reaction.	Slight to moderate irritation from prolonged exposure. Repeated exposure may cause allergic reaction.	Not likely to cause irritation or allergic reaction.
OTHER HAZARDS		Delayed health hazards or severe reactivity hazards should be noted. For example, suspected carcinogen, pyrophoric, hypergolic, etc.		* The LC_{50} for gases or vapors, ppm (vol.). ** The LC_{50} for mists, fumes, or dusts.	

DMCC/90

Table 2. NIST Labeling System: List of NIST Labels

LABEL NUMBER	LABEL SIZE, CENTIMETERS	COLOR OF LABEL PRINT	COLOR OF LABEL BORDER	HAZARD LEVEL (SIGNAL WORD)	LABEL USED ON
100-1-0889	12.70 X 17.78	Black-on-White	Red	High (DANGER)	New, Used or Waste Chemicals
100-2-0889	12.70 X 17.78	Black-on-White	Orange	Moderate (WARNING)	New, Used or Waste Chemicals
100-3-0889	12.70 X 17.78	Black-on-White	Yellow	Low (CAUTION)	New, Used or Waste Chemicals
100-4-0889	12.70 X 17.78	Black-on-White	Green	Very Low (PLNR)*	New, Used or Waste Chemicals
100-5-0889	12.70 X 17.78	Black-on-White	Red Stripe	High (UNKNOWN HAZARDS)**	New, Used or Waste Chemicals
100-11-0889	5.72 x 9.84	Black-on-	Red	High (DANGER)	New, Used or Waste Chemicals

		White			
100-12-0889	5.72 X 9.84	Black-on-White	Orange	Moderate (WARNING)	New, Used or Waste Chemicals
100-13-0889	5.72 X 9.84	Black-on-White	Yellow	Low (CAUTION)	New, Used or Waste Chemicals
100-14-0889	5.72 X 9.84	Black-on-White	Green	Very Low (PLNR)*	New, Used or Waste Chemicals
100-15-0889	5.72 X 9.84	Black-on-White	Red Stripe	High (UNKNOWN HAZARDS)**	New, Used or Waste Chemicals
100-21-0889	4.13 X 10.80	Black-on-White	Red	High (DANGER)	New, Used or Waste Chemicals
100-22-0889	4.13 X 10.80	Black-on-White	Orange	Moderate (WARNING)	New, Used or Waste Chemicals
100-23-0889	4.13 X 10.80	Black-on-White	Yellow	Low (CAUTION)	New, Used or Waste Chemicals
100-24-0889	4.13 X 10.80	Black-on-White	Green	Very Low (PLNR)*	New, Used or Waste Chemicals
100-25-0889	4.13 X 10.80	Black-on-White	Red Stripe	High (UNKNOWN HAZARDS)**	New, Used or Waste Chemicals
100-51-0889	12.70 X 17.78	Black-on-White	White	---------	New, Used or Waste Chemicals
100-52-0889	5.72 X 9.84	Black-on-White	White	---------	New, Used or Waste Chemicals
---------	1.27 X 5.08	Black-on-Red	------	High (DANGER)	Vendor Labeled Containers, compressed Gas Cylinders, and Liquified Gas Containers to Identify the "Owner and Date" Received
---------	1.27 X 5.08	Black-on-Orange	------	Moderate (WARNING)	
---------	1.27 X 5.08	Black-on-Yellow	------	Low (CAUTION)	
---------	1.27 X 5.08	Black-on-Green	------	Very Low(PLNR)*	
---------	0.95 X 3.81	Red-on-Yellow	---------	***	Vendor or NIST Labeled Containers to Indicate that the Substance Contains a "CANCER-SUSPECT AGENT" or a "KNOWN CANCER AGENT"
---------	0.95 X 3.81	Red-on-Yellow	---------	***	
---------	1.27 X 5.08	Red-on-White	---------	****	"PEROXIDIZABLE COMPOUNDS" to Indicate the Dates Received and Opened and the Date to be Discarded or Tested

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** Hazards are unknown (e.g., the compound is a synthesized substance or one not adequately characterized on an MSDS) and a worst case hazard level (and corresponding label color) is assigned.

*** Hazard classification (level) must not be lower than "Low" when this mandatory special label is affixed to the container. Use of substances controlled (regulated) by OSHA, requires continuous inventory control and use-authorization by the NIST/MASC Safety Office--see HSI 10.

**** Hazard level varies with each individual peroxidizable compound and will be properly determined by recognition of peroxidizable chemical structure and diligent use of the appropriate MSDS and the NIST Labeling Guide. This label is mandatory on all peroxidizable compounds--see HSI 6.

Used as a supplementary "Contents" label where needed and for inventory control where desired.

Table 3. Container Capacity Limitations* for Flammable and Combustible Liquids Stored in the Lab.

	CONTAINER MATERIAL		
	Glass or Approved Plastic	**Metal****	**Safety Cans**
Flammable Liquids			
Class IA	0.47l (1 pint)†	3.79l (1 gallon)	7.57l (2 gallons)
Class IB	0.95l (1 quart)†	18.93l (5 gallons)	18.93l (5 gallons)
Class IC	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)
Combustible Liquids			
Class II	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)
Class III	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)

* Limitations apply to new, excess, used, or waste liquids.

** Excludes DoT metal drums.

† The use of larger glass or plastic containers requires an exemption from the NIST/MASC Safety Office and must meet OSHA 29CFR1910.106 requirements. If the use of larger glass containers [up to 3.79l (1 gallon)] is permitted, they must be stored in approved carriers or containers capable of holding the contents of the glass container.

Definitions

Flammable Liquid: A Class I liquid having a flash point below 37.8°C (100°F) and a vapor pressure not exceeding 276 kPa (40 psia) at 37.8°C (100°F).

Class 1A liquids have flash points below 22.8 °C (73 °F) and boiling points below 37.8C (100°F).
Class 1B liquids have flash points below 22.8°C (73 °F) and boiling points at or above 37.8°C (100°F).
Class 1C liquids have flash points at or above 22.8° C (73°F) and below 37.8°C (100°F).

Combustible Liquid: A liquid having a flash point at or above 37.8°C (100°F).

Class II liquids have flash points at or above 37.8°C (100°F) and below 60°C (140°F).
Class IIIA liquids have flash points at or above 60°C (140°F) and below 93.4°C (200°F).
Class IIIB liquids have flash points at or above 93.4°C (200°F).

Flash Point: The minimum temperature at which a liquid within a test vessel gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid, as determined by appropriate ASTM test procedures and apparatus.

Source: Adapted from NFPA Code 45 (August 1991) and OSHA 29CFR1910.106 (July 1991).

Table 5. Cross Reference of Hazard Codes for the NIST Labeling Guide.

FLAMABILITY

Label Color	Label Signal Words	Flash Point	OSHA/NFPA Class. (NFPA Rating)**	CERCLA Rating
Red	DANGER	F.P. <-6.7°C (F.P. <20°F)	IA(4), IB(3)	3
Orange	WARNING	-6.7°C≤F.P <37.8°C (20°C≤F. P. <100°F)	IA(4), IB(3), IC(3)	3
Yellow	CAUTION	37.8°C ≤F. P. <93.3°C (100°F ≤F. P. <200°F)	II(2), IIIA(2)	2
Green	PLNR*	F. P. ≥ 93.3°C (F. P.≥<200°F)	IIIB(1)	1

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.
** Many manufacturers use the NFPA hazard rating system and flammable/combustible liquid classification system.

REACTIVITY

Label Color	Label Signal Words	NFPA Rating (CERCLA Rating)	Comments
Red	DANGER	4[3]	Will readily explode or detonate or decompose explosively at room temperature and pressure.
Orange	WARNING	3[3] and 2[2]	Normally unstable and will readily undergo violent chemical change (without detonation), or will detonate or explosively decompose with strong initiator, or will react explosively with water.
Yellow	CAUTION	1[1]	Normally stable but becomes unstable at elevated temperatures and pressures, or reacts with water with nonviolent energy release.
Green	PLNR*	0[0]	Normally stable, even under fire conditions, and does not react with water. Not likely to react in a manner that will produce harmful results.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

HEALTH HAZARD-Skin Absorption

Label Color	Label Signal Words	LD_{50}**	Comments
Red	DANGER	$LD_{50} \leq 200$ mg/kg	A single prolonged exposure, or rapid absorption, may be fatal.
Orange	WARNING	$200 < LD_{50} \leq 1000$	A single prolonged exposure, or mg/kg rapid absorption, may be harmful. Repeated exposure may be fatal.
Yellow	CAUTION	-----	Repeated exposure may result in absorption of harmful amounts.
Green	PLNR*	-----	Not likely to be harmful.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** LD_{50} (Median Lethal Dose) values are given in milligrams of chemical substance per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

HEALTH HAZARD-Inhalation

Label Color	Label Signal Words	LD_{50}#	Comments
Red	DANGER	$LC_{50} \leq$ 200 ppm for 1 hr (gases & vapors) $LC_{50} \leq$ 2mg/liter for 1 hr (fumes, mists, dusts)	A single short exposure may cause serious adverse effects, even death.
Orange	WARNING	200 < $LC_{50} \leq$ 2000 ppm for 1 hr (gases & vapors) 2 < $LC_{50} \leq$ 20 mg/liter for 1 hr (fumes, mists, dusts)	A single short exposure may cause adverse effects. Prolonged exposure may cause death.
Yellow	CAUTION	---------	A single exposure may cause irritation or asphyxia. Prolonged exposure may cause adverse effects.
Green	PLNR*	---------	Not likely to cause adverse effects.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

LC_{50} (Median Lethal Concentration) values are given in parts per million by volume of chemical gas or vapor in air--or in milligrams of chemical substance per liter of air for toxic mists, fumes, or dusts--when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

HEALTH HAZARD-Ingestion

Label Color	Label Signal Words	LD_{50}**	Comments
Red	DANGER	$LD_{50} \leq$ 50 mg/kg	Highly toxic. A single oral dose may be fatal.
Orange	WARNING	50 < $LD_{50} \leq$ 500 mg/kg	Toxic. A single oral dose can be harmful, even fatal.
Yellow	CAUTION	-----	Slightly toxic. A single oral dose may be harmful.
Green	PLNR*	-----	A single oral dose is not likely to be harmful.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** LD_{50} (Median Lethal Dose) values are given in milligrams of chemical substance per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

HEALTH HAZARD-Eye/Skin Contact

Label Color	Label Signal Words	Comments
Red	DANGER	Corrosive. A single short exposure may cause severe burns or blindness.
Orange	WARNING	Severe irritation may occur. Prolonged exposure may cause burns. Repeated exposure may cause strong allergic reaction.
Yellow	CAUTION	Slight to moderate irritation may occur upon prolonged exposure. Repeated exposure may cause allergic reaction.
Green	PLNR*	Not likely to cause irritation or allergic reaction.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

HEALTH HAZARD-Overall**

Label Color	Label Signal Words	NFPA Rating [CERCLA Rating]	Comments
Red	DANGER	4[3], 3[3]	Very short term exposure can cause death or major residual injury, even if medical attention is received promptly.
Orange	WARNING	2[2]	Short term exposure can cause severe and lasting health problems.
Yellow	CAUTION	1[1]	Significant exposure can cause undesirable health effects.
Green	PLNR*	0[0]	No known adverse health effects.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** In the absence of detailed test data in each of the four subcategories of HEALTH HAZARD (Skin Absorption, Inhalation, Ingestion, and Eye/Skin Contact), the NFPA or CERCLA Ratings can be used as a reasonable guide to the overall HEALTH HAZARD assessment and its associated label color.

NIST Compressed Gas Safety Procedures

COMPRESSED GAS CYLINDERS

1. PURPOSE

This Health and Safety Instruction is issued to provide guidelines and a set of general rules pertaining to safety in the storage, handling and use of compressed gas cylinders.

2. INTRODUCTION

a) Using compressed gas cylinders in laboratories presents many problems not generally encountered in industrial use. These problems include the variety of flammable, toxic and radioactive materials and special mixtures with properties that are frequently unfamiliar to the researcher. The tendency of laboratory personnel is to modify, adapt, and repair cylinder valves and regulators themselves, rather than to leave such work to the supplier or specially trained personnel. Incorporating a cylinder into an experimental apparatus so that foreign materials can enter the cylinder or so that the cylinder or systems may be subjected to extreme pressures is an extremely hazardous practice that unfortunately has been fairly common in some research laboratories.

b) Compressed gas cylinders can be safely used in laboratories if the NFPA codes and following general rules (as published in the CRC Handbook of Laboratory Safety) are complied with completely during cylinder receiving operations, storage, transportation to the laboratory or other use point, usage and return of empty cylinders.

3. LECTURE BOTTLES

a) Using cylinders other than lecture bottles is encouraged. Many suppliers will no longer accept lecture bottles for return and NIST must pay a high cost to dispose of them.

b) If you must use a lecture bottle, check with the suppliers and use one who will allow you to return it. Even though the returnable lecture bottle may cost more, not having to pay the disposal cost will offset the high purchase cost.

4. GENERAL RULES

a) Know the Gas and its Properties: Researchers should know the properties and hazards of the gases they are going to use. Knowledge of the gases properties is essential to laboratory operations due to the unusual uses to which gases may be put, as well as the uncommon gases or special gas mixtures used. Not only should the flammability, corrosiveness or oxidation potential be known but also the physiological properties must be kept in mind--such as toxic, anesthetic, or irritating qualities. Two examples are carbon monoxide, which is both toxic and flammable, and hydrogen sulfide, which is toxic and has the ability to desensitize the sense of smell. A copy of the gases' Material Safety Data Sheet (MSDS) should be available for review by the researchers and emergency services personnel.

b)Labeling Cylinders/ Cylinders with Unknown Contents: All compressed gases cylinders and liquified gas containers are to be appropriately labeled in accordance with Section 6 of HSI No. 15, Chemical Container Labeling (see 6.8 Special Labels). More specifically, compressed gas cylinders and liquefied gas containers **must** bear some legible marking, tag or label to clearly indicate their contents (e.g., hydrogen, fluorine, propane, etc.) **AND** an appropriately color-coded NIST *Owner and Date* label. Do not remove this identification marking from empty cylinders as this might present a hazard to the supplier. Also, do not rely on color codes for cylinder content identification as this varies from supplier to supplier, and many persons are color blind.

5. CYLINDERS CONTAINING TOXIC GAS

a) What are Toxic Gases? Toxic gases are those with an NFPA 704[1][1] Health Hazard Rating 3 or 4 or having a Health Hazard Rating of 2 with no physiological warning properties.

b) Storing Toxic Gases: When new storage areas are designed or existing ones are renovated, toxic gases must be stored in continuously mechanically ventilated gas cabinets. Toxic gases with a Health Hazard Rating of 4 will require a gas detection system.

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[1][1]NFPA 704: Standard for the Identification of the Fire Hazards of Materials for Emergency Response, 1996 Edition

c) Using Toxic Gases: When renovating or making major modification to a lab that uses or will use a toxic gas, the cylinders must be stored in a continuously mechanically ventilated hood or gas cabinet. No more than three (3) of these cylinders may be stored in a hood or gas cabinet. A listing of chemicals and their NFPA Health Hazard Ratings can be found at http://www.orcbs.msu.edu/chemical/nfpa/nfpa.html

6.CYLINDER STORAGE AND USE

a) Store Cylinders Appropriately: Store and use cylinders in ventilated areas away from heat and ignition sources. Segregate flammable gases from other gases, particularly oxygen. Limit the quantity stored in one location. Cylinders containing gases under high pressure could very quickly render an area unsafe if the large volume of gas should be released. Most cylinders, except those in toxic gas service, are equipped with safety relief devices of the rupture disk or spring-loaded type. The rupture disc type pressure-relief devices may function prematurely if cylinders are heated to a temperature in excess of 52 C (125 F) and release the entire content of the cylinders. Also, cylinders containing low vapor pressure liquids could become liquid filled at elevated pressures and burst. If a cylinder must be heated, this should be done in a very well thermostated water bath heated to no more than 52 C (125 F). However, this is a hazardous procedure at best, and should be avoided, especially with full cylinders.

b) Securely Fasten Cylinders: Whether in use or being stored, all cylinders must be securely fastened. If a cylinder should fall or roll off a bench, the regulator or valve might break off and release a large quantity of gas. This may cause the cylinder to pinwheel, which can injure employees or damage equipment. Another danger is that the valve could shear off and the cylinder might "rocket" like a projectile due to the sudden release of pressure. The storeroom stocks supports (clamps) available for securing cylinders to a bench, a wall, etc. Where cylinders must stand away from a wall or bench, cylinder stands for large (6" to 9 1/4"diameter cylinders), small (4" to 6" diameter cylinders) and lecture bottle (2" diameter) are commercially available. Although there are innumerable commercial holders, stands, etc., available for supporting cylinders, a length of chain, cable or rope can also be used to secure a cylinder to a work bench or other fixed object. The main consideration is that cylinders must be adequately secured.

c) Keep Caps on Cylinders Not in Use: Caps used for valve protection should be kept on the cylinder except when the cylinder is in use. Removing the cap when **not** using the cylinder, exposes the valve to being damaged and leaking.

d) Maximum Number of Cylinders in a Lab: The following table from NFPA 45 *Standard on Fire Protection for Laboratories Using Chemicals, 1996 Edition* gives the maximum number of compressed or liquefied gas cylinders that may be place in a laboratory work area.

Maximum Number of Compressed or Liquefied Gas Cylinders in a Laboratory Work Area

	Flammable or Oxidizing Gases		Liquefied Flammable Gases		Gases with Health Hazard Rating of 3 or 4
	Sprinklered Space	Nonsprinklered Space	Sprinklered Space	Nonsprinklered Space	Sprinklered or Nonsprinklered Space
Max. No. of cylinders per 46.5 m^2 (500 ft^2) or less	6	3	3	2	3

e) Do Not Tamper with Cylinders: Never tamper with cylinder valve, safety plugs or packing nuts. Tampering with these could create a leak and a potentially hazardous atmosphere. If a hazardous condition is created in the laboratory, exit the lab and call for emergency help. There have been fatalities in laboratories caused by unfamiliarity with valves. In one instance, the safety nut was confused with an outlet cap, which is frequently installed on the outlet, and the safety nut was completely removed. Note that the safety nut connects directly to the valve inlet (pressure side) and once removed, the flow of gas cannot be stopped.

f) Leaking Cylinders: Leaking cylinders should be marked as leakers and removed to an open area until picked up by the supplier. Do not put unmarked leaking cylinders among the empties. DOT transportation regulations forbid shipping leaking containers by common carrier. Note: Call X2222 (X7777 in Boulder) for assistance with leaking cylinders.

g) Do Not Strike Arcs on Cylinders: Do not strike an electric arc on cylinders. This rule is directed primarily to industrial users, where inert gases are used for shielded arc welding. It is very tempting to test the arc on the large metal surface. Arc burns, however, not only are stress raisers, but due to metallurgical changes, could cause the heat affected portion of the cylinder to become brittle.

h) Use Compressed Gases with Appropriate Equipment: Only use regulators that are suitable for the cylinder. Proper mating hardware should fit; do not force the connection. Do not use homemade adapters. The importance of this rule cannot be overemphasized. Accidents have occurred because of attaching flammable gas regulators to oxygen cylinders, improperly identifying the contents of a cylinder, and so forth. American National/Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections lists the various standard connections for compressed gases. The connections listed are classified into four thread divisions. There are left and right-hand threads and internal and external threads, plus some pipe threads and yoke type connections. The various gases are assigned to connections so that hazardous interconnections cannot be made. Generally speaking, left-hand threads are reserved for flammable gases and right-hand threads for nonflammables. There are a few exceptions made necessary by previous practice. Almost always, hazardous connections cannot be made except by homemade adapters or by forcing the connection.

i) Use of Cylinder Regulators: Cylinders contain pressures greater than the pressures which most laboratory equipment can withstand, even steel or nonferrous tube. Always use a regulator with high-pressure cylinders (above 500 psi). The inadvertent closing of a vent valve or stopcock or the plugging of a line or mercury trap could cause a violent failure of the apparatus. There are fine needle valves available which can reduce the flow of gas from the high-pressure cylinder to a few bubbles a minute. Such valves are not regulators and the design of any equipment used with them must keep this fact in mind. Use needle valves only with low-pressure cylinders (below 500 psi). Valves are only flow regulators, not pressure regulators.

j) Close Cylinder Valves When Not in Use: Do not stop the gas flow from cylinders overnight by only backing off on the regulators. Even the best of regulators can develop seat leaks and allow excessive pressures to develop in using equipment. Closing the cylinder valve will eliminate this hazard. If this rule is followed meticulously, any question as to the position of a cylinder valve in an emergency is removed. Finally, no foreign materials can enter the cylinder if through leakage or other malfunction the cylinder pressure should become lower than the pressure in some other part of the apparatus.

k) Close Valves on Empty Cylinders and Mark the Cylinder Empty or “MT": If cylinders are returned to the supplier with the valve open, the interior will become contaminated with atmospheric air and moisture. Such cylinders cannot be used for high purity gases without extensive reconditioning. If the cylinder had contained such materials as anhydrous hydrogen chloride, or chlorine, this resultant humid atmosphere would corrode the cylinder very rapidly. Empty cylinders should be so marked “MT” and stored separately to avoid returning full cylinders to the supplier or sending empties to the laboratories or other use point.

l) Never Attempt to Refill a Cylinder: It is very tempting to refill your own small cylinders from large ones by interconnecting them with high pressure tubing. There are a number of reasons why this practice is hazardous. The cylinder being filled may have a lower working pressure than the large cylinder. Filling too rapidly can result in extremely high cylinder temperatures which could damage the valve. The cylinder being filled may contain a residue of a reactive material. It is extremely difficult to completely purge a cylinder. For cylinders containing liquids, DoT prescribes filling weights which allow for a vapor space at temperatures and pressures for which the safety device functions. If these weights are exceeded, the cylinders may become liquid-full at room temperatures and fail. Finally, at least one supplier of laboratory gases uses a very lightweight welded, thin-wall aluminum, or one-time use cylinder (i.e., DoT 39) which is classified as non-refillable by DoT. For safety reasons such a single-use cylinder must be discarded after use the same as the common aerosol spray cans.

7. TRANSPORTING AND HANDLING CYLINDERS

a) Handle Cylinders Carefully: Cylinders are primarily shipping containers and as such are constructed to be as light as possible consistent with safety, durability and pressurization requirements. Cylinders should be moved with great care, preferably strapped to a cart. As the valve assembly is the weakest part of the cylinder, avoid striking the valve against anything. Rough handling or abuse could seriously weaken the cylinder and render it unfit for further use.

b) Transport Cylinders Safely: Transport large cylinders only on a wheeled cart. Do not slide or roll them even one at a time, since it is easy to lose control of a cylinder while rolling or dragging no matter how much practice a person might have. If one falls, it could land on the foot. Additionally, avoid dragging cylinders as this procedure introduces

other manual handling hazards. Mishandling of cylinders in transit is the cause of many pulled muscles, back injuries and foot injuries.

Appendix A-1

NFPA HEALTH HAZARD RATING SYSTEM*

A health hazard is any property of a material which, either directly or indirectly, can cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation, or ingestion.

Rating	Description
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment is given, including those which are too dangerous to be approached without specialized protective equipment. This degree includes: materials which can penetrate ordinary rubber protective clothing; materials which under normal conditions or under fire conditions give off gases which are extremely hazardous (i.e., toxic or corrosive) through inhalation or contact with or absorption through the skin. Examples of compressed and/or liquefied gases of this degree include: Cyanogen, Fluorine, Hydrogen Cyanide and Hydrogen Fluoride.**
3	Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment is given, including those requiring protection from all bodily contact. This degree includes: materials giving off highly toxic combustion products; materials corrosive to living tissue or toxic by skin absorption. Examples of compressed and/or liquefied gases of this degree include: Anhydrous Ammonia, Chlorine, Diborane, Ethylamine, Hydrogen Bromide, Hydrogen Chloride, Hydrogen Sulfide, Methylamine, Methyl Bromide and Phosphine.**
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given, including those requiring use of respiratory protective equipment with independent air supply. This degree includes: materials giving off toxic combustion products; materials giving off highly irritating combustion products; materials which either under normal conditions or under fire conditions give off toxic vapors lacking warning properties. Examples of compressed and/or liquefied gases of this degree include: 1,3-Butadiene, Carbon Monoxide, Dimethyl Ether, Ethyl Chloride, Ethylene Oxide, Formaldehyde, Methyl Chloride, Methyl Mercaptan, Sulfur Dioxide, Tetrafluoroethylene, Trimethylamine, Vinyl Bromide and Vinyl Chloride.**
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given, including those which require use of an approved canister type gas mask. This degree includes: materials which under fire conditions would give off irritating combustion products; materials which on the skin could cause irritation without destruction of tissue. Examples of compressed and/or liquefied gases of this degree include: Acetylene, r.-Butane, iso-Butane, 1-Butene, 2-Butene,Cyclopropane, Ethane, Ethylene, Methane, Natural Gas, iso-Pentane, Propane, Propylene and Vinyl Fluoride.**

Appendix B-1

FLAMMABILITY CHARACTERISTICS OF COMMON COMPRESSED AND LIQUIFIED GASES

This list is not inclusive or exhaustive. Practically all compressed and liquified gases present varying health hazards to personnel. Therefore, users are urged to seek additional information from reliable references to adequately assess the reactivity or toxicity of the material. Contact the Safety Office in Gaithersburg (X5818) or the MASC Safety Office in Boulder (X3948) for additional information, as needed.

GAS	FLAMMABLE RANGE (if Flammable, percent by vol.)	REFERENCE SOURCE	GAS	FLAMMABLE RANGE (if Flammable, percent by vol.)	REFERENCE SOURCE

Acetylene	2.5 - 82	MGD	Hydrogen Cyanide[1]	5.6 - 40	325M, 627
Allene[1]	1.5 - 11.5	MGD	Hydrogen Fluoride	(a)	
Ammonia[1]	15 - 28	MGD	Hydrogen Iodide	(a)	
Arsine[1]	(b)	MGD	Hydrogen Selenide[1]	(b)	
Boron Trichloride	(a)	MGD	Hydrogen Sulfide	4 - 44	325M, 627
Boron Trifluoride	(a)	MGD	Ketene	(b)	
1,3-Butediene[1]	2 - 12	627	Methane	5 - 15	325M, 627
n-Butane[1]	1.6 - 8.4	325M	Methylacetylene[1](Propyne)	2 - 11.1	325M
iso-Butane[1]	1.8 - 8.4	325M	Methylamine[1]	4.9 - 20.7	325M
I-Butene[1]	1.6 - 10	627, 325M	Methyl Bromide[1]	10 - 16	325M
2Butene	1.7 - 9.7	627	3 - Methyl-1-butene[1]	1.5 - 9.1	325M, 627
Carbon Monoxide	12.5 - 74	627	Methyl Chloride[1]	8.1 - 17.4	325M
Carbonyl Chloride (Phosgene)	(a)		Methyl Fluoride[1]	(b)	
Carbonyl Fluoride	(a)		Methyl Mercaptan[1]	3.9 - 21.8	325M
Carbonyl Sulfide[1]	12 - 29	325M	2-Methylpropene	1.8 - 9.6	325M, 627
Chlorine	(a)		Natural Gas	3.8/6.5 - 13/17	325M
Chlorine Dioxide	(a)		Nitric oxide	(a)	
Chlorine Trifluoride	(a)		Nitrogen Dioxide	(a)	
1-Chloro-l,l-Difluorethane[1]	9 - 14.8	MGD	Nitrogen Trioxide	(a)	
Chlorotrifluoroethylene[1]	8.4 - 38.7	MGD	Nitrogen Trifluoride	(a)	
Cyanogen[1]	6 - 32	MGD	Nitrosyl Chloride	(a)	
Cyanogen Chloride[1]	(a)		Oxygen	(a)	
Cyclopropane[1]	2.4 - 10.4	MGD, 627	Oxygen Difluoride	(a)	
Deuterium	5 - 75	325M	Ozone	(a)	
Diazomethane	(b)		iso-Pentane[1]	1.4 - 7.6	325M
Diborane	0.8 - 88	325M, 627	Perchloryl Fluoride	(a)	
1,1-Difluoroethane[1]	3.7 - 18	MGD	Phosphine	(c)	
1,1-Difluoroethylene[1]	5.5 - 21.3	MGD	Propane	2.1 - 9.5	325M, 627

Dimethyl Ether[1]	3.4 - 27	325M, 627	Propylene[1]	2.0 - 11.1	325M
2,2-Dimethytpropane[1]	1.4 - 7.5	325M, 627	Selenium Hexafluoride	(a)	
Ethane	3.0 - 12.5	325M, 627	Silane	(c)	
Ethytacetylene[1]	(b)		Silicon Tetrafluoride	(a)	
Ethylamine[1]	3.5 - 14	325H	Stibine	(b)	
Ethyl Chloride[1]	3.8 - 15.4	325M	Sulfur Dioxide	(a)	
Ethylene	2.7 - 36	325M, 627	Sulfur Tetrafluoride	(a)	
Ethylene Oxide[1]	3 - 100	MGD	Sulfuryl Fluoride	(a)	
Fluorine	(a)		Tetrafluoroethylene[1]	10/11 - 50/60	MGD, 325M
Formaldehyde	7 - 73	325M	Tetrafluorohydrazine[1]	(b)	
Germane	(b)		Trimethylamine[1]	2 - 11.6	MGD, 325M
Hexafluoroacetone	(a)		Vinyl Bromide[1]	9 - 15	325M
Hydrogen	4 - 75	325M, 627	Vinyl Chloride[1]	3.6 - 33	325M, 627
Hydrogen Bromide	(a)		Vinyl Fluoride[1]	2.6 - 21.7	MGD
Hydrogen Chloride	(a)		Vinyl Methyl Ether[1]	(b)	

[1]Liquefied Gases

Notes on Flammable Range:(a) - Not flammable,(b) - Flammable but range not reported, (c) - Spontaneously flammable

Reference source for flammable ranges: 325-NFPA 325 - *Guide to Fire Hazard Properties of Flammable liquids, Gases, and Volatile Solids*

627-U.S. Bureau of Mines Bulletin 627, *Flammability Characteristics of Combustible Gases and Vapors*

MGD-*Matheson Gas Data Book*

Chemical Glove Resistance Guide

Chemical Name	NFPA Health Rating	Nitrile	Natural Rubber Latex	Recommended Alternate Material
ACETALDEHYDE	3	P	G	
ACETIC ACID (GLACIAL)	3	F	G	
ACETIC ANHYDRIDE	3	F	G	
ACETONE	1	F	G	
ACETONITRILE	2	F	F	Butyl (E)
ACRYLIC ACID	3	G	G	
AMMONIUM ACETATE		E	E	
AMMONIUM CARBONATE		E	E	
AMMONIUM FLUORIDE, 30-70%	3	E	E	
AMMONIUM HYDROXIDE,30-70%		E	E	
AMMONIUM HYDROXIDE, <30%		E	E	

AMYL ALCOHOL	1	E	G	
ANILINE	3	F	G	
AQUA REGIA		P	P	Neoprene (F)
AZT			G	
BENZALDEHYDE	2	P	F	Butyl (E)
BENZENE	2	F	P	Viton (G)
BORIC ACID		E	G	
BROMOPROPIONIC ACID		F	G	
BUTYL ACRYLATE	2	P	P	Teflon (G)
BUTYL CELLUSOLVE		G	G	
CALCIUM HYDROXIDE		E	E	
CARBON DISULFIDE	3	G	P	
CARBON TETRACHLORIDE	3	P	P	Viton (G)
CHLOROBENZENE	2	P	P	Viton (G)
CHLORODIBROMOMETHANE		P	P	Viton (G)
CHLOROFORM	2	P	P	Polyvinyl Alcohol (G)
CHLORONAPTHALENES	1	P	P	Viton (G)
CHROMIC ACID	3	F	P	(G)
CISPLATIN		G	G	
CITRIC ACID, 30-70%		E	E	
CYCLOHEXANE	1	E	P	
CYCLOHEXANOL	1	E	G	
CYCLOHEXANONE	1	P	P	Butyl (G)
CYCLOHEXYLAMINE	3	P	P	
DI-N-AMYLAMINE	3	E	P	
DI-N-BUTYLAMINE	3	E	P	
DI-N-BUTYLPHTHALATE	0	E	F	
DI-N-OCTYLPHTHALATE	0	E	F	
DIACETONE ALCOHOL	1	G	F	
DIALLYLAMINE		P	P	Viton (G)
DICHLOROACETYL CHLORIDE	3	P	P	Viton (G)
DIESEL FUEL	0	E	P	
DIETHANOLAMINE	1	E	E	
DIETHYLAMINE	3	G	F	
DIETHYLENE GLYCOL	1	E	E	
DIETHYLENETRIAMINE	3	P	P	Neoprene (G)
DIISOBUTYL KETONE	1	G	P	
DIISOBUTYLAMINE	3	E	P	
DIMETHYL ETHER		G	P	
DIMETHYL SULFOXIDE (DMSO)	1	G	E	
DIMETHYLACETAMIDE	2	F	G	
DIMETHYLFORMAMIDE (DMF)	1	P	P	Butyl (G)
1, 3-DIOXANE		P	F	Butyl (G)
1, 4-DIOXANE	2	P	P	Butyl (G)
EPICHLOROHYDRIN	3	P	F	Butyl (G)
ETHANOL	0	G	G	
ETHYL ACETATE	1	P	F	Butyl (G)
ETHYL ETHER	1	G	P	
ETHYLENE GLYCOL DIMETHYL ETHER	2	F	F	Butyl (G)
ETHYLENE DICHLORIDE	2	P	P	Polyvinyl Alcohol (E)
ETHYLENE GLYCOL	1	E	E	
FORMALDEHYDE, 30-70%	3	E	G	
FORMIC ACID	3	G	E	
FREON 113 OR TF		E	P	
FREON TMC		F	F	Polyvinyl Alcohol (E)
FURFURAL	3	P	P	Butyl (G)
GASOLINE, 40-50% AROMATICS	1	E	P	
GASOLINE, UNLEADED	1	G	P	
GLUTARALDEHYDE, <5%		G	G	
GLYCEROL		E	E	

HEPTANES	1	E	P	
HEXANE	1	E	P	
HYDRAZINE	3	E	F	
HYDROCHLORIC ACID, <30%	3	G	E	
HYDROCHLORIC ACID, 30-70%		G	G	
HYDROFLUORIC ACID,<10%	4	G	G	
ISOBUTYL ALCOHOL	1	E	P	
ISOOCTANE	0	E	P	
ISOPROPYL ALCOHOL	1	E	E	
ISOPROPYLAMINE	3	P	P	Teflon (G)
JET FUEL <30% AROMATICS 73-248C	1	G	P	
KEROSENE		E	P	
LACTIC ACID		E	E	
LAURIC ACID		E	E	
MALATHION,30-70%		G		
MALEIC ACID		G	G	
METHANOL	1	F	F	Neoprene (G)
METHYL ACETATE	1	P	P	Butyl (G)
METHYL ETHYL KETONE	1	P	P	Butyl (E)
METHYL ISOBUTYL KETONE	2	P	P	Butyl (G)
METHYL METHACRYLATE	2	P	P	Polyvinyl Alcohol (E)
METHYLENE CHLORIDE	2	P	P	Polyvinyl Alcohol (G)
AMYL ACETATE	1	F	P	Butyl (G)
BUTYL ACETATE	1	F	P	Butyl (G)
BUTYL ALCOHOL	1	E	E	
N-METHYL-2-PYRROLIDONE	2	P	E	
N-NITROSODIETHYLAMINE		P		Butyl (G)
PROPYL ALCOHOL		E	E	
NAPHTHA, 15-20% AROMATICS		E	P	
NAPHTHA , <3% AROMATICS	1	E	P	
NITRIC ACID, <30%	3	G	G	
NITRIC ACID, 30-70%	3	P	P	Neoprene (G)
NITROBENZENE	3	F	F	Butyl (G)
NITROETHANE	1	P	G	
1-NITROPROPANE	1	P	F	Butyl (G)
2-NITROPROPANE	1	P	P	Butyl (G)
OCTANE	0	G	P	
OCTYL ALCOHOL	1	E	E	
OLEIC ACID	0	E	G	
OXALIC ACID	3	E	E	
PALMITIC ACID		G	F	
PCB (POLYCHLORINATED BIPHENYLS)	2	G	P	
PENTACHLOROPHENOL	3	G	P	
PENTANE	1	E	P	
PERCHLORIC ACID, 30-70%	3	F	F	Neoprene (F)
PERCHLOROETHYLENE	2	G	P	
PEROXYACETIC ACID		P	P	Butyl (G)
PETROLEUM ETHERS, 80-110C	1	G	P	
PHENOL	4	F	F	(F)
PHOSPHORIC ACID	3	G	F	
PICRIC ACID	3	E	G	
POTASSIUM HYDROXIDE	3	E	G	
POTASSIUM IODIDE		G	G	
PROPYL ACETATE	1	F	P	Butyl (F)
PYRIDINE	3	P	P	Butyl (G)
SODIUM CARBONATE		E	E	
SODIUM CHLORIDE		E	E	
SODIUM FLUORIDE	3	G	G	
SODIUM HYDROXIDE,30-70%	3	G	E	
SODIUM HYPOCHLORITE		E	E	

SODIUM THIOSULFATE		G	G	
STYRENE	2	P	P	Polyvinyl Alcohol (G)
SULFURIC ACID, <70%	3	F	G	
SULFURIC ACID, >70%	3	P	P	Butyl (G)
TANNIC ACID	0	G	G	
1,1,1,2-TETRACHLOROETHANE		F	P	Viton (G)
TETRAHYDROFURAN	2	F	P	Teflon (G)
TOLUENE	2	F	P	Viton (G)
TOLUENE-2,4-DIISOCYANATE (TDI)	3	P	P	Butyl (G)
1,2,4-TRICHLOROBENZENE	2	F	P	Teflon (G)
1,1,1-TRICHLOROETHANE	2	P	P	Viton (G)
1,1,2-TRICHLOROETHANE	2	P	P	Viton (G)
TRICHLOROETHYLENE	2	P	P	Viton (G)
TRICRESYL PHOSPHATE	2	G	G	
TRIETHANOLAMINE	2	E	E	
TURPENTINE	1	E	P	
XYLENES	2	F	P	Viton (G)

The National Fire Protection Association (NFPA) has developed a system for indicating the health hazards of chemicals:

4	**Danger, may be fatal on short exposure. Specialized protective equipment required.**
3	**Warning, corrosive or toxic.**
2	**Warning, may be harmful if inhaled or absorbed.**
1	**Caution, may be irritating.**
0	**No unusual hazard.**
	No information available. Avoid skin contact or inhalation..

The compatibility of the glove films with each chemical is color coded as follows:

P	**POOR chemical resistance**
F	**FAIR chemical resistance**
G - E	**GOOD to EXCELLENT chemical resistance**

List of Chemicals and Gases Used at the NIST CNST Nanofab-Reference

The dangers of each chemical is summarized in the table below following the NFPA Hazard Classification, and can be found in the MSDS books located in the main entrance of the Nanofab.

Flammables	H	F	R	C	Acids	H	F	R	C	Oxidizers	H	F	R	C	Caustic	H	F	R	C	Gases	H	F	R	C
2-Propanol	2	3	2	3	Acetic	3	2	2	4	Ammonium Peroxidisulfate	2	1	1	3	25% Tetramethyl-ammonium Hydroxide	3	1	1	4	Helium	0	0	0	0
Acetone	1	4	2	1	Silicic	2	0	0	1	Hydrogen Peroxide	3	0	3	4	Potassium Hydroxide	3	0	2	4	Forming Gas N2/H2	0	2	0	0
Ethyl Alcohol	3	3	0	0	Sulfuric:	2	0	1	3	Xenon Difluoride	1	0	1	3	Ammonium Hydroxide	3	0	1	4	Oxygen	0	0	0	0
Hexamethyldisilazane	2	4	2	0	PAE Etchant (Phosphoric Acid Etch)	3	0	2	3						MF-321 e-Beam Resist Remover	4	0	2	4	Hydrogen	0	4	0	0
Methanol	3	3	1	3	Buffered Oxide Etch	4	0	2	4						Microposit 351 Developer	4	0	2	4	Nitrous Oxide	1	0	0	0
Methyl Alcohol	3	3	1	3	CR 9 Chromium Etchant	2	2	2	3											Trifluoromethane	1	0	0	0
Microposit 1165 Remover	2	3	1	1	CR 7 Chromium Etchant	2	2	2	3											Silane	2	4	3	0
RS 100 Photoresist Stripper	2	3	0	0	Hydrochloric	3	0	2	4											Oxygen	3	0	0	0
Tetramethylammonium Hydroxide 25% (TMAH)	3	1	1	4	Hydrofluoric	3	0	2	4											Nitrogen	1	0	0	0
Xylene	2	4	1	0	Nitric	4	0	3	4											Ammonia	3	1	0	3
					Phosphoric	3	0	2	4											Argon	0	0	0	0
																				Dichlorosilane	4	4	2	3
																				5% Silane/Helium	2	4	3	0
																				Sulfur Hexafluoride	1	0	0	0
																				Chlorine	4	0	0	3
																				Boron Trichloride	3	0	2	3
																				Octafluoro-cyclobutane	1	0	0	0
																				Carbon Tetrafluoride:	1	0	0	0

Table 2- Nanofab Chemicals and NFPA Hazard classification: Health, Flammability, Reactivity, Contact

NFPA Hazard Classification	Health	Flammability	Reactivity	Contact
4	Deadly	Flash Point < 73° F	Explosive at room Temperature	Extremely damaging
3	Extreme Danger	Flash Point < 100° F	Shock and heat may detonate	Severe damage
2	Hazardous	Flash Point > 100° F < 200° F	Violent Reaction with water	moderate damage
1	Slightly Hazardous	Flash Point > 200° F	Unstable if heated, not violent	Slight damage
0	Normal Material	Will not burn	not reactive with water	Low or no danger

Table 3- National Fire Protection Agency Hazard Classification Chart